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Anomalies in the Foreign Exchange Returns and Implied Volatilities

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Abstract

This thesis examines patterns in the FX returns and implied volatilities using daily return and implied volatility data for four major exchange rates for a period of January 1994 to December 2003. The existence of the patterns could indicate that the FX market is not efficient and could provide a basis for the construction of the trading strategies.

Volatility tends to rise prior to the announcement of both scheduled and unscheduled news and fall on the announcement day. The "sign effect", indicated by the bad news having stronger impact on the volatility than good news, tends to weaken in post euro period. We find a strong evidence of the day of the week effect in the FX returns and implied volatilities, indicated by (i) positive Thursday and negative Friday returns, (ii) positive implied volatility changes on Monday and Tuesday and (iii) negative implied volatility changes on Thursday and Friday. The intraweek patterns have become more significant after the introduction of euro. We confirm the holiday and January effect that tends to strengthen in the "bad" years characterized by low GDP growth rate, and tends to weaken in the "good" years characterized by high GDP growth rate.

We find a strong relation between implied volatility and contemporaneous returns, which is strongly affected by the news announcements, stronger for small returns and whose significance declines following the introduction of euro. There is also some evidence of the extreme levels of the implied volatility predicting following day returns, which is found to be particularly significant for negative (as opposed to positive) returns and for extremely large increases (as opposed to decreases) in the level of the implied volatility. The evidence presented in this thesis contributes to the existing research on FX anomalies, with the main contribution centring around a significant impact of euro.

Contents

CHAPTER 1. INTRODUCTION

The foreign exchange (FX) market is the largest financial market in the world. Today foreign currency trading is a widespread activity: the daily turnover of the global FX market stands at about 2 trillion dollars, with at least 80% of all the deals being represented by speculative transactions (Lyons, 2001). The FX market is the over the counter market and the major market participants are dealers, brokers and customers. The organizations trading at the FX market include banks, export and import companies, multinational corporations, hedging funds, governments and other entities. A complete description of the FX market is given by Lyons (2001). The development of the electronic trading and a succession of overlapping business hours has resulted in high volume, twenty-four hour trading. All these factors contributed to the formation of the patterns in the currency return and volatility series, which is the topic of this work. Many studies have tried to identify the patterns in the returns and volatilities, specifically to determine whether the prices and volatilities differ across time, at different times of the day, between days, before and after the release of the macroeconomic information or before and after the random events of both an economic and political nature. The purpose of this thesis is to study the calendar patterns in FX returns and implied volatilities. We also test the impact of news announcements on the FX implied volatilities and explore the relation between FX return and implied volatility series. The study covers 10-year period, from January 1994 to December 2003, with the hypothesis being tested for the 5-year time intervals of 1994-1998 and 1999-2003, which represent pre euro and post euro periods, allowing to study an impact of euro on the FX calendar patterns.

Understanding the sources and reasons of calendar effects is important for rationalizing observed patterns and for making predictions about market outcomes. Various explanations have been provided for the calendar effects. The most obvious one is the data problems and the resulting spurious results. Another explanation relies on the strategic behavior of market participants in anticipation to regulations and legislation. Real and information trading frictions, and other market imperfections, such as taxes, settlement procedures and trade gaps may distort the optimal functioning of the market, creating arbitrage opportunities, and therefore seasonality patterns. Calendar effects could also be explained by the investor irrationality, such as slow response to information, due to various factors, such as effects of framing, the use of heuristics and agency problems. Other more popular explanations for the seasonality patterns in the asset return and volatility series include systematic fluctuations in liquidity surpluses/needs, the arrival rate of private information and public news announcements. A large body of evidence suggests that the calendar effects are attributed to not one, but several forces, including all of the above, that collectively have more or less regular influence at particular moments of time and do not occur merely by chance.

If the calendar effects do exist, they could be used to develop the trading strategies that could generate returns in excess of the transaction costs. Although this is outside the scope of our study, one could argue that given a positive relation between implied volatility and option price, it could be possible to make profit by issuing an option prior to the expected fall in the implied volatility, when the option price is high and buying it back when the implied volatility is expected to rise[1]. Alternatively, one could buy an option prior to the expected rise in the implied volatility and sell it when the volatility is expected to fall. Although Harvey and Whaley (1992), Ederington and Lee (1996) and Kim and Kim (2004) showed that it would be difficult to obtain abnormal trading profits (after adjusting for the transaction costs) based on the observed patters in the equity, interest rate and FX futures markets, respectively, their findings show that abnormal returns could be generated when the underlying price volatility is relatively low.

The remainder of this chapter is structured as follows. In section 1.1, we highlight the importance of our study from both academic and practical perspectives. Section 1.2 provides an overview of the research objectives, while section 1.3 summarizes main findings of our study. We discuss main contributions of our work in section 1.4, and discuss the main outline of this thesis in section 1.5.

[1] A delta neutral position (eg a combination of a put and a call) could be created to hedge against a loss due to unfavourable changes in the underlying FX rates

1.1. Research Importance

Published academic papers on calendar anomalies go back to early thirties (Fields, 1931, 1934). The test of price, return and volatility anomalies has always been interesting topic, since the existence of the anomalies directly indicates the violation of the efficient market hypothesis. According to Fama's (1970) efficient market hypothesis, asset prices reflect information and if markets are efficient, then new information is reflected quickly rather than slowly into the market prices. If markets are efficient, then asset prices are likely to follow random walk process[2], implying zero correlation between price changes and trading time. This makes it impossible for the traders to forecast a future path of the financial asset prices and rules out the possibility of making abnormal returns (confirmed by Kendall, 1953, Rozeff and Kinney, 1976 and Officer, 1975).

According to the efficient market hypothesis, the distribution of returns is normal and is assumed to be identical for all days of a week. French (1980) believed that the day of the week effect in the US equity market could be due to the bad information released after Friday close, suggesting that if the markets were efficient, then this negative information would not cause a systematic fall in the prices (since investors and traders would discount prices throughout the week). The existence of the market anomalies does not lead to the rejection of the efficient market hypothesis, but indicates the violation of the weak form of the efficient market hypothesis. The markets are efficient in a weak form if the prices cannot be predicted based on the historic information. If the systematic patterns exist in the short-term financial asset prices, then weak form of market efficiency no longer holds. Following French (1980), various papers studied seasonality patterns: Kato (1990) investigated day of the week effects in Japanese equity markets, while Aggarwal and Rivoli (1989) investigated seasonality patterns in four emerging markets. Vetter and Wingender (1996) studied the January effect in the stock markets, and Cornett et. al (1995) published a paper on the intraday patterns in the FX futures. For the volatility series, Harvey and Huang (1991) provided an evidence of the day of the week effect

[2] Random walk is a sufficient, but not a necessary condition, for a market to be efficient.

in the volatility of the currency futures traded on the Chicago Mercantile Exchange's (CME) International Monetary Market (IMM). Rogalski and Maloney (1989) concluded that there is a turn of a year effect in the equity implied volatilities, but failed to find any evidence of a turn of a month effect (later confirmed by Barone-Adesi and Cyr, 1994).

The study of the FX anomalies is important not only for academics, but also for practitioners, since it makes traders, investors, quantitative specialists and financial analysts aware of the regular shifts in the asset prices and allows them to incorporate the patterns in the trading models. Calendar patterns are very important for risk management purposes, such as hedging, computing value at risk, or even for trading with options for the speculative reasons. Understanding the dynamics of financial markets is at least as important to private investors and financial institutions as it is to policy makers and the economy as a whole. The knowledge of the patterns does not guarantee profit because of the transaction costs, but provides some insights to investors (Berument and Kiymaz, 2001). Some studies (Jordan and Jorda, 1991, Agrawal and Tandon, 1994, and Riepe, 1998) showed that the calendar anomalies and patterns should be traded out of existence once they are identified as they (patterns) are incorporated into trading models used to price financial assets and develop trading strategies. Others (Pettengill and Jordan, 1988, Cadsby and Ratner, 1992 and Haugen and Jorion, 1996) suggested that these patterns persist, sometimes for a long period of time.

The study of the FX implied volatility properties and its impact on the exchange rates has additional practical implications. According to the financial press[3], extremely high levels of the implied volatility are associated with the market lows, and therefore with the signaling attractive entry levels for long trades. Given a positive relation between implied volatility and option price, it could be possible to make profit by issuing an option prior to the expected fall in the implied volatility (eg

[3] in an article "Fixated on the VIX: soaring volatility means fear - and opportunity", K. Tan was writing in the July 29, 2002 issue of Barron's that "A big VIX spike indicates the kind of extreme fear contrarians associate with market bottoms".

on a particular day or prior to a particular event), when the option price is high and buying it back when the implied volatility is expected to rise. Alternatively, one could buy an option prior to the expected rise in the implied volatility and sell it when the volatility is expected to fall. Although Harvey and Whaley (1992), Ederington and Lee (1996) and Kim and Kim (2004) showed that it would be difficult to obtain abnormal trading profits (after adjusting for the transaction costs) based on the observed patters in the equity, interest rate and FX futures markets, respectively, their findings show that abnormal returns could be generated when the underlying price volatility is relatively low. Therefore, by identifying the FX implied volatility patterns and relations, the traders could incorporate these patterns into their models and trade based on those patterns.

Implied volatilities can also be used to make stress testing in risk management more effective, by warning risk managers of large price moves. Stress testing is designed to "estimate potential losses in abnormal markets", as defined by Laubsch (1999), and is one of the market indicators used by risk managers to predict extreme asset price movements. Risk managers are interested in such indicators, including implied volatilities, because they have to account for asset returns not displaying a normal distribution, which is the violation of one of the main assumptions of the standard risk management models, like delta hedging and value–at-risk (VaR) models. Since options enable market participants to tailor their exposures to large price moves, option prices provide a warning signal of large movements in asset prices, including exchange rates. They tend to rise when market anticipates or fears greater volatility.

1.2. Research Objectives

This thesis has four general objectives, summarized below:

1. *What is the Impact of News Announcements on the FX Implied Volatility?*
2. *What are the Calendar Seasonality Patterns in FX Returns and Implied Volatilities?*
3. *What is the Relationship Between FX Returns and Implied Volatilities?*
4. *What is the Impact of Euro on the FX Patterns in Returns and Implied Volatilities?*

This section provides a summary of each of these objectives.

1.2.1. Announcement Effect in the FX Implied Volatilities

The first empirical chapter studies the impact of sixteen US macroeconomic variable announcements, the minutes of the Federal Open Market Committee (FOMC), the announcement of the official US interest rate changes, and central bank interventions on the implied volatility of the major exchange rates.

We examine the behavior of the FX implied volatility prior to, on the day of and following the news announcements. We use both scheduled and unscheduled news announcements in order to understand whether the impact of scheduled news on the FX implied volatility is different from that of unscheduled ones. We hypothesize that FX implied volatility could increase prior to not only scheduled (given that the timing of the scheduled news is known in advance, market uncertainty tends to increase prior to the news releases), but also unscheduled[4] news covered in this study (interest rate and central bank interventions). Following news announcement, we expect implied volatility to decline in the case of the scheduled

[4] Implied volatility is likely to exhibit patterns prior to the interest rate changes or interventions, given that in some occasions, the market anticipates news even if they are unscheduled, while in others, the news could occur in response to a particular pattern in the implied volatility

news (as the source of uncertainty disappears) and increase in the case of unscheduled news, as more uncertainty is created. Besides, we study the impact of the surprise element of the news announcements, measured by the difference between actual and expected results, claiming that news with the surprise element should create more uncertainty. We also try to understand whether the announcement effect is asymmetric by differentiating between large vs. small and positive vs. negative surprise element (good or bad news). We hypothesize that bad news should become more important in the good times when economy is doing well, while positive news should have more significant impact on the FX implied volatility during recession.

In the same empirical chapter, we study the impact of Bank of Japan's (BoJ) interventions on the FX implied volatilities, by differentiating between Japanese Yen purchases and sales. Besides the impact of BoJ's presence in the market on the FX implied volatilities, we also study the impact of the magnitude of its interventions on the FX implied volatilities. We hypothesize uncertainty and therefore implied volatility should increase prior to the interventions as market anticipates the central bank's involvement, while volatility should surge once the interventions occurs. We also expect to find at least some relation between the magnitude of interventions and FX implied volatility changes as interventions involving larger amounts should affect implied volatility more.

1.2.2. Calendar Seasonality Patterns in FX Returns and Implied Volatilities

In the second and third empirical chapters we study seasonality patterns in the FX return series and implied volatilities. We study day of the week effect, differentiating between days with and without news announcements. Besides, we examine other calendar patterns, and specifically:

- Monthly effects to find an evidence of a January effect
- Intra-monthly patterns to find an evidence of first half of the month and turn of the month effects

- Turn of the year effect
- Quarterly effects for FX implied volatilities
- Holiday effect for pre and post holiday days

The existing literature on the return and implied volatility seasonality in the equity markets provide an evidence of the above mentioned calendar patterns. We hypothesize that the seasonality in the equity markets should drive calendar patterns in the FX markets. For example, a tax loss selling, which explains January effect, turn of the year effect and the monthly patterns (eg November[5] in USA and April in UK) is likely to create capital flows and therefore result in the FX seasonality. The tendency of many FX transactions to occur during particular periods (eg financial statement disclosures, payment of the municipal and corporate debt) could explain some intra-monthly and quarterly patterns.

For the return series, we attempt to study the dynamic feature of the January effect by differentiating between years with high and low GDP growth rates – consistent with the existing literature, we expect to find stronger January effect in low GDP growth years. For the implied volatilities, we study turn of the year effect by observing implied volatilities during 30 days prior to and following a turn of the year. We expect implied volatility to increase prior to the year end (explained by the tax loss selling) and decline after the year end as the source of uncertainty disappears.

1.2.3. Relationship Between FX Returns and Implied Volatilities

The purpose of the final chapter is to study the relation between FX returns and implied volatilities. The chapter covers three main areas:

- the contemporaneous relation between FX returns and implied volatilities
- the asymmetric feature of this relation and finally

[5] Tax year end for the mutual funds in the US

- the ability of the FX implied volatility to predict future returns

In the first case, the attempt is made to test a hypothesis that the relations that exist between simultaneous changes in the implied volatility and asset returns at the equity and bond markets also exist at the FX market. In addition, the impact of the magnitude of the price changes, regardless of the sign of the change, on the implied volatility is tested by including additional variable into the equation. In the second case, the regression model is designed to capture an impact of large vs. small and positive vs. negative returns on the currency market implied volatility. Besides, the volatility – return relation is studied on both the announcement and non-announcement days. Finally, in the last case, the ability of the implied volatility to indicate overbought or oversold market conditions and therefore to predict future returns is studied.

1.2.4. Impact of Euro

The choice of the sample period of 1994-2003 provides an opportunity to break the entire sample into two sub-samples, representing five years prior to and five years after the introduction of Euro as a single currency in January of 1999. One of the reasons our study is important is that we have an opportunity to test the impact of euro on the FX calendar patters. If the currency markets have become more volatile following the introduction of Euro, we would expect FX seasonality patterns to become more pronounced. In contrast, we also hypothesize that if the FX market became less volatile, seasonality patterns should weaken. Besides, the USD depreciation in the post euro period and the evidence that the calendar anomalies are more pronounced in a declining rather than a rising market (Fishe et. al, 1993 and Arsad and Coutts, 1997 and Steeley, 2001) implies that the calendar patterns should be significantly stronger in 1999-2003 sample period compared to 1994-1998. However, many papers showed that as traders exploit documented and well-known anomalies, the seasonality patterns tend to fade out, which would result in weaker patterns in post euro period.

1.3. Research Findings

This thesis consists of four empirical chapters listed below.

1. *Announcement Effect in the FX Implied Volatilities*
2. *Calendar Seasonality Patterns in FX Returns*
3. *Calendar Seasonality Patterns in FX Implied Volatilities*
4. *Relationship Between FX Returns and Implied Volatilities*

This section provides a summary of the findings of each empirical chapter.

1.3.1. Announcement Effect in the FX Implied Volatilities

FX Implied volatility tends to rise prior to the announcement of both scheduled and unscheduled news, explained by the presence of the informed traders, and fall on the announcement day. However, the BOJ interventions tend to cause a further increase in volatility, which can be explained by the additional uncertainty brought by the central bank. Results also suggest that for most macroeconomic indicators, the mere announcement of the news, rather than the "surprise" element, affects currency market volatility. In addition, the results confirm the existing findings on the "sign effect", indicated by the bad news having stronger impact on the volatility than good news, but additionally, provides an evidence of the weakening sign effect in the period of 1998 – 2003.

1.3.2. Calendar Seasonality Patterns in FX Returns

There is an evidence of the day of the week effect in the FX return series, indicated by positive Thursday and negative Friday returns, and explained by the invoicing patterns in the world trade and the response of speculator and dealers to the major scheduled news announcements. Since there is less opportunity in the currency market for informed trader to take advantage of uninformed traders, there is little evidence of the Monday effect, documented for equity markets. Although, there are no intra-month patterns in FX return series, January and November returns are negative, while December, June and September returns are positive. The month of the year effect could be explained by the tax loss-selling hypothesis, actions of speculators and dealers prior to the holidays, money managers' inclination to make long-term reassessments of FX trends at the end and beginning of the calendar year, the timing of disclosure in the financial statements[6] and the portfolio rebalancing by investors.

The January effect tends to strengthen in the "bad" years characterized by low GDP growth rate, and tends to weaken in the "good" years characterized by high GDP growth rate. There is also the turn of the year effect in the FX markets, which becomes more significant in 1999-2003 period. This could be explained by the fact that the portfolio managers sell loss-making stocks to realize capital gains and losses in the last three days in December, resulting in USD depreciation. Average daily returns are positive prior to the holidays and negative following the holidays, which is explained by the tendency of the banks to flatten their natural long USD positions prior to the official holidays. Lack of evidence in support of the phenomenon documented for the equity markets (e.g. Monday effect, returns around holidays being similar to that around weekends) suggest that the calendar seasonalities in the FX market are different from those in the equity market due to the difference in the market structures.

1.3.3. Calendar Seasonality Patterns in FX Implied Volatilities

There is a strong evidence of the day of the week effect in the FX implied volatilities, indicated by the positive implied volatility changes on Monday and Tuesday that could be explained by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) and negative implied volatility changes on Thursday and Friday that could be explained by the announcement effect.

[6] With the globalization and increased role of the multinational corporations, the timing of the financial statement disclosures could create calendar patterns in the FX returns and implied volatilites, given that they (disclosures) are associated with the increased activity in the FX markets.

The intraweek patterns have become more significant after the introduction of euro in 1999. Although, there is little evidence in support of the monthly and quarterly patterns, the results suggest that there is an evidence of the turn of the year and turn of the month effects in the FX implied volatilities. The turn of the year effect, indicated by the increasing volatility between days -30 and +2, and a declining volatility between days +2 and +10, could be explained by Rogalski and Maloney's (1989) seasonal risk premium hypothesis and the concentrated liquidity-trading hypothesis of Lakonishok and Smidt (1986). Increased volatility around the turn of the month is explained by the substantial payments to private investors in the US economy and the fact that most corporate and municipal debt in the USA is payable on the first and last days of a month, affecting USD volatility. Implied volatility tends to fall prior to and increase following the official holidays. Since the market activity during and around the holidays resembles the behavior of the volatility during and around the weekends, the holiday effect could be explained by the private information hypothesis of Foster and Viswanathan (1990).

1.3.4. Relationship Between FX Returns and Implied Volatilities

The results indicate that there is a strong relation between implied volatility and contemporaneous returns, whose significance declines following the introduction of euro. Large exchange rate movements, regardless of their direction, are found to be associated with increased implied volatility. Both positive and negative returns lead to the increased market uncertainty, affecting implied volatility to the same extent. In spite of the lack of a strong evidence of the volatility asymmetry, small returns tend to have stronger impact on the implied volatility, compared to large returns, which could be explained by the behavior of the option traders. Besides, the impact of the contemporaneous returns on the FX implied volatility tend to be stronger when the announcement days are excluded from the sample, which could be explained by the fact that on the announcement days, the rise in the implied volatility, resulting from the USD depreciation is offset by the fall in the implied volatility resulting from the release of the important news announcements (Ederington and Lee, 2001). Finally, no significant evidence of the relation between

FX implied volatilities and forward looking returns is found, but there is some evidence of the extreme levels of the implied volatility predicting following day returns. In addition, the impact of the extreme levels of the implied volatility on the forward looking returns, is found to be particularly significant for negative (as opposed to positive) returns and for extremely large increases (as opposed to decreases) in the level of the implied volatility.

1.4. Research Contributions

Our thesis offers several contributions to the existing literature on the FX calendar patterns and the relation between FX returns and implied volatilities. We present general contributions in section 1.4.1, and provide an overview of others contributions specific to the empirical chapters in sections 1.4.2, 1.4.3, and 1.4.4.

1.4.1. General Contributions

The focus on the FX market is a contribution of this thesis to the existing literature on the volatility patters. Several studies have examined the properties of asset prices and implied volatilities in the equity and interest markets (Fleming and Remolona, 1997, 1999, Balduzzi et. al, 2001 and Nikkinen and Sahlstrom, 2004). However, relatively little is known about the dynamics of exchange rates and implied volatilities derived from the currency options markets. Using FX markets is preferable as, conducting the study at the stock market causes the problem of thin trading, also known as the non-synchronous trading problem. This is probably due to the fact that the options and underlying stocks are traded at the same time (stock exchanges work for 6-7 hours a day). The FX market is open for 24 hours a day, so the problem of thin trading is almost eliminated when the study is conducted with the currency options. The FX market is also the most liquid and the largest financial market in the world in terms of the turnover with low transaction costs. FX does not have definite closures since it is organized around partially overlapping trading sessions in the regional centres worldwide. Another advantage of the study conducted at the FX volatility over the stock market volatility is that it is possible to study the impact of the events that take place and news released during non-trading hours of the organized stock exchanges.

The second contribution is that we cover a ten-year period of 1994-2003, which includes the five years after the adoption of Euro. The existing literature on the FX market dynamics focuses on the 1980s and 1990s, with only few papers covering late 1990s (Yamori and Kurihara, 2004). The use of the sample period of

1994-2003 provides an opportunity to break the entire sample into two sub-samples, representing five years prior to and five years after the introduction of Euro as a single currency in January of 1999. This is important contribution given the dynamic feature of the seasonality patterns (Hiraki and Maberly, 2003) and the significant changes in the global economy in the late 1990s and the first years of this decade, which result in the changes in the seasonality patterns and market dynamics. As the globalization of the financial markets and capital market liberalization have been accelerated since the mid 1990s and as the euro was introduced in 1999, it is particular interesting to investigate the development of new seasonality patterns and relations in the currency markets.

Thirdly, in our study, FX volatility is measured by the implied volatilities, which is an ex ante measure of volatility, obtained from the leading data providers (Reuters and Dow Jones). Ex post volatility measures, such as variance of the returns, standard deviations and number of price changes are a backward-looking measure of recent volatility conditions, reporting what actually happened rather than the market expectation of the event (Rogalski and Maloney, 1989). As suggested by Bailey (1988), ex post volatility measures are based on the past information and therefore do not capture the impact of various factors on volatility. In order to overcome the problem with the ex post measure of volatility, volatilities implied from the options prices, which is an ex ante measure of volatility and are more accurate predictors of subsequently realized price volatility (Bailey, 1986 and Scott and Tucker, 1989) are used. Besides, the use of FX implied volatilities reported by the market makers via Reuters and Bloomberg screens, instead of volatilities implied from the option prices using models, like Black-Scholes (1973) increases accuracy and reliability of the results.

1.4.2. Announcement Effect in FX Implied Volatilities – Contributions

The fourth contribution of this study is that while major published papers on the announcement effect in the FX market focuses on a single exchange rate, this study focuses on all four major exchange rates. Most published papers focus only on one currency pair. For example, Ederington and Lee (1993) and Andersen and Bollerslev (1998)) studied USD/DEM volatility, while Ito and Roley (1987) and Kim et. al (2004) focused on the USD/JPY volatility. Goodhart et. al (1993) studied the impact of news announcements on the volatility of USD/GBP. Although, there are some papers, which cover several exchange rates (Madura and Tucker, 1993 and Bauwens et. al, 2005 who cover USD/EUR and USD/GBP), none of the recent papers on the impact of the news releases on the FX implied volatility covers all four major exchange rates.

Fifthly, this thesis extends the work by Kim et. al (2004), who covered six and the one by Bauwens et. al (2005), who covered nine macroeconomic indicators, by studying the impact of 16 scheduled announcements of the US macroeconomic indicators. In spite of the fact that the initial studies focused only on the scheduled news announcements (Ederington and Lee, 1993, 1995), the effect of the scheduled news on the FX volatility has been shown to be substantially different from those of unscheduled news (Bauwens, 2005). Therefore, we study the impact of news other than the scheduled macro indicator announcements, extending the study by Ederington and Lee (1993, 1995, 1996) and Kim et. al (2004) by covering the minutes of FOMC meetings, and extending the study of FOMC minutes by Nikkinen and Sahlstrom (2004) by focusing on the occasions when FOMC has amended a US official interest rate. In addition, this thesis contributes to the existing literature and specifically extends the works of Laakkonen (2004) and Bauwens et. al (2005), by concentrating on each of the individual news announcements. Although Laakkonen (2004) and Bauwens et. al (2005) covered 60 and 21 announcements, respectively, they studied an impact of all news announcements, taken as the whole, on the currency market volatility. The advantage of our study is that instead of aggregating the news announcements into composite news measures, each of 16 scheduled macroeconomic indicator releases as well as central bank interventions and interest rate announcements are treated separately. In other words, our model allows to capture the effect of each of the announcements on the currency implied volatility, with the aim of identifying the news announcements that tend to have the strongest impact on the FX implied volatility.

Sixthly, this study extends the previous studies by Donders and Vorst (1996) and Ederington and Lee (1996), by examining the behavior of implied volatility not only on the announcement day but also separately on days surrounding the release day. Compared to Nikkinen and Sahlstrom (2003), who studied the impact of the news announcements on the stock market volatility before and after the announcement day, this study focuses the behavior of the stock market implied volatility five rather than one day before and after the news release.

Seventh, we also study the impact of the central bank interventions on the FX volatility, resulting in some further contributions. In comparison with the empirical studies by Bonser-Meal/Tanner (1996), Dominguez (1998), and Galati/Melick (1999) this study uses the actual dates of BoJ interventions announced by BoJ rather than those reported by the financial press. Before 2002, when the BoJ released the official dates of its intervention behavior, the researchers used interventions reports in the financial press as a proxy for BoJ intervention policy. Frenkel et. al (2003) compared the official BoJ interventions dates with a proxy variable used in an empirical study by Ramaswamy and Samiei (2000) and concluded that the financial press underestimated the overall intervention activity of the BoJ by roughly 25 percent. Unlike Frenkel et. al (2003), who studied intervention – volatility correlation for USD/JPY only, this thesis covers not only USD/JPY, but also USD/EUR, USD/GBP and USD/CHF volatility. The intervention-volatility correlation has been studied not only for the intervention days, but also for the days surrounding these days. Finally, unlike early studies by Bhattacharya and Weller (1995), Baillie and Humpage (1992) and Baillie and Osterberg (1997), this study uses ex-ante (implied) measure of volatility rather than GARCH and EGARCH estimates of conditional exchange rate volatility. The key advantage of using implied volatilities to estimate the intervention-volatility correlation is that implied volatilities are forward-looking variables by nature, and allow to capture the effect of the uncertainty caused by the central bank intervention.

Eighth, we contribute to the existing literature by extending the study of the news announcements' impact on the FX volatility to the stochastic component of the news releases. A stochastic component reflects the surprise effect due to the discrepancy between the actual contents of the news and the expected contents before the release. A study of the relationship between a surprise element of the macro announcement and market volatility is important since according to the efficient market hypothesis, only the surprises should affect the markets (Almeida et. al, 1998). Additionally, Andersen et. al (2003) argued that the existence of the significant relationship between unanticipated shocks to fundamentals and exchange rates would be consistent with the predictions of the rational expectations theory. This study also studies an asymmetric impact of the news announcement on the FX volatility. Although there is some literature on the impact of the announcements with large vs. small and positive vs. negative surprise elements on the FX return series (Aggarwal and Schirm, 1998), the literature on the asymmetric impact of the announcements on the FX volatility is limited. In spite of the presence of some papers, which use different methodology and different data set to study an impact of positive and negative news (Brown et al., 1988, Campbell and Hentschel, 1992 and Haugen et al., 1991), there is no published paper on the impact of large and small macro announcements on the FX volatility.

1.4.3. Calendar Seasonality Patterns in FX Returns and Implied Volatilities – Contributions

Ninth, we contribute to the existing literature on the FX anomalies, by covering patterns in the currency return series and implied volatilities, which have never been studied before. Although there is some, though limited literature on the day of the week (Cornet et. al, 1995 and Yamori and Kurihara, 2004) and the turn of the month (Liano and Kelly, 1995 and Aydogan and Booth, 1999) effects in the FX return series, the existing literature on other seasonality patterns is limited to the equity markets. Our study extends the work on the return intra-monthly patterns (Ariel, 1987, Lakonishok and Schmidt, 1988 and Ogden, 1990), the turn of the year effect (Jacobs and Levy, 1988), the January effect (Givoly and Ovadia, 1983 and

Jones et. al, 1991), the month of the year effect (Bhabra et. al, 1999) and the holiday effect[7] (Ariel, 1990, Howe and Wodd, 1993 and Wood, 1994) to the major cash currency markets. Besides, we extend the work by Jones and Singh (1997) and Chen and Zhou (2001) on the stock volatility seasonality patterns and by Ferris et. al (2003) on the commodities volatility seasonality patterns to the currency market.

Tenth, we contribute to the existing literature on the FX return anomalies, by studying a link between news announcements and the day of the week effect. Cornet et. al (1995) and Yamori and Kurihara (2004) mentioned that the announcement effect could explain the day of the week return anomalies in the currency markets, but none of the published papers actually studied this link. Building upon the recognition that the announcement effect explains the intraweek patterns in the FX implied volatilities (Harvey and Whaley, 1992, Ederington and Lee, 1996 and Ederington and Lee, 2001), we try to explain the intraweek patterns in the FX return series by the scheduled US macroeconomic announcements.

Another contribution of our study is that the volatility patterns in the cash FX market are studied[8]. The FX market is a 24-hour market composed of the sequential and partially overlapping trading periods in the regional centers worldwide. The market does not have definite closures, except those generated by the trading hours in particular regions. Although, the use of the implied volatilities from options on cash markets is associated with problems, such as price difference in the cash market due to bid-ask spreads and different closing times between cash and option markets (Kim and Kim, 2004), it solves the problem of thin trading and non-trading effect documented by Figlewski (1997)[9]. Besides, currency implied volatilities are drawn from the over-the-counter (OTC) markets, which are considerably more liquid than

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[7] Aydogan and Booth (1999) studied the holiday effect for the Turkish FX market, while Liano (1995) studied the pre holiday effect in the currency futures

[8] Most of the existing papers on the FX volatility intraweek patterns focused on the FX futures market (Han et. al, 1999 and Kim and Kim, 2004).

[9] Thin trading, also known as non-synchronous trading problem arises due to the options and underlying assets (stocks or FX futures) trading at the same time. Non-trading effect arises, because of a lack of trading during particular times of a day or a week, which results in the full impact of large information event being spread over two or more days and therefore asset returns displaying positive autocorrelation that reduces estimated volatility. The FX cash market is a 24 hour market, so the problem of thin trading and non-trading effect is almost eliminated when the study is conducted with the currency options.

the currency futures options. Castren and Mazzotta (2005) showed that since the trading volume in OTC options is often much larger than in the corresponding market traded contracts, the underlying liquidity on OTC quotes is deeper, which makes the OTC quotes a more reliable source for information extraction. In summary, the 24-hour nature of the FX market, high liquidity and low transaction costs resulting from the fact that the FX is the largest financial market in the world increases the accuracy of the data used in this study.

Twelfth, throughout the thesis, we test additional hypothesis in order to contribute to the existing literature on the return anomalies. For example, we study a link between the FX January effect and the market direction, examine the impact of both US and non-US holidays on the FX market, and conduct additional testing of the tax loss hypothesis.

1.4.3. Relation Between FX Returns and Implied Volatilities – Contributions

Thirteenth, we contribute to the existing literature on the asymmetric impact of the contemporaneous returns on the implied volatility (Davidson et. al, 2001, Giot, 2003, Kim and Kim, 2004), by differentiating between not only, positive and negative returns, but also between large and small returns. Fourteenth, the impact of the FX returns on the implied volatility is studied for both the announcement and non-announcement days. Fifteenth contribution is that by studying an asymmetric impact of the FX returns on the implied volatility in both low and high volatility environments, our work extends the empirical study by Giot (2003) on the stock indices, to the currency market. Sixteenth, the asymmetric feature of the relation between extreme levels of the implied volatility and forward looking returns is studied.

1.5. Structure

The remainder of this thesis is organized as follows. The next chapter examines empirical findings on the announcement effect in the financial market volatilities, discusses calendar patterns in asset returns and volatilities and provides an overview of some empirical findings of the volatility – return relation in the financial markets. In chapter 3, a description of the data sets used in the study is provided, while chapter 4 describes regression estimation models and hypothesis proposed to detect FX anomalies and volatility – return relation.

The results of the empirical analysis are presented in chapters 5 through 8. Specifically, chapter 5 focuses on the announcement effect in the FX implied volatilities. Chapters 6 and 7 examine calendar seasonality patterns in the FX return series and implied volatilities, respectively. Chapter 8 analyses relation between FX returns and implied volatilities. Finally, chapter 9 concludes and provides some potential weaknesses and points for further research.

CHAPTER 2. LITERATURE REVIEW

In this chapter, we examine empirical findings on the seasonality patterns in the financial market volatilities, highlighting the key areas within the existing literature our thesis would contribute to. Although we highlight numerous contributions of our piece in the previous chapter, we summarize the major gaps in the existing literature that we intend to fill by formulating three key reasons why we examine the existing literature in the first place.

1. Is there any evidence of the seasonality patterns that we intend to test? Most of the exiting studies on the seasonality patterns that we test in our thesis have documented the existence of some form of anomaly or relation in the financial market returns and volatilities. However, based on the existing literature, it appears that most of these patterns are not stable over time- they appear in some periods, disappear in certain periods and reappear in others. Given that the latest studies on the FX seasonality patterns tend to cover the period prior to late 1990s with only few extending beyond January 1999 (when Euro was officially adopted as a single European currency), our study contributes to the existing literature by covering the sample period during five years after the introduction of euro. The use of the more recent period provides us an opportunity to compare our findings to the results of the previous studies and therefore to identify the patterns that emerged or faded over time.

2. Which financial markets do existing studies focus on? Although there is an extensive literature on most seasonality patterns covered in our piece, the existing literature on many anomalies and seasonalities is limited to the equity markets. For some patterns, the existing literature on the FX market is virtually non-existent, while for others the focus is on the FX futures, as opposed to FX cash markets. The coverage of the FX cash market would help to fill a gap in the existing literature on the FX calendar effects and resolve the problem of thin trading, also known as the non-synchronous trading problem (via the focus on the cash rather than futures market).

3. What type of data has been used in the existing literature? Most of the existing studies use a limited number of the variables (eg announcements) to explain prices changes and volatility in a limited number of the exchange rates over a limited period of time. We contribute to the existing literature by using more extensive data (eg sixteen macro announcements, including the surprise element of those news releases, as well as interest rate and central bank intervention announcements, both US and non US holidays) to explain price changes and volatility in all four major FX rates using a ten year period enabling us to compare FX volatility behavior prior to and after the introduction of euro.

The existing findings on the following topics are discussed in this chapter:

1. *Announcement effect in volatilities*
2. *Calendar patterns in the FX return series*
3. *Calendar patterns in the FX implied volatilities*
4. *Relation between returns and volatilities*

The remainder of this chapter is structured as follows. In section 2.1, we highlight the findings of the studies on the implied volatility announcement effect, clarifying the areas our research would contribute to. Sections 2.2 and 2.3 focus on the FX calendar patterns in return and implied volatility series, respectively, while section 2.4 summarizes main findings on the relation between return and implied volatilities. In Section 2.5, we discuss the existing literature on the impact euro had or is expected to have on the FX market and finally, section 2.6 provides a summary and highlights contributions that our study will offer to the existing literature.

2.1. ANNOUNCEMENT EFFECT IN VOLATILITIES

Although, the initial literature on the announcement effect focused on the financial asset prices (Almeida et. al, 1998, and Simpson and Ramchander, 2005), there exists some literature on the announcement effect in the implied volatilities, which document a significant impact of the news announcements on the FX volatilities. The existing literature uses Reuters headlines, scheduled and unscheduled macro announcements, headlines of financial newspapers (Chan et. al, 2001) as the proxy for the information flow. Implied volatility was found to increase prior to scheduled announcements and decrease following the announcements. The release of the unscheduled news announcements, such as interventions, tends to drive market uncertainty up, causing an increase in implied volatility. Besides, the announcement effect is more pronounced for bad news and especially when the economy is weak.

The latest studies on the announcement effect cover the period prior to the introduction of Euro with only few extending beyond January 1999, when the euro was officially adopted as a single European currency. Our study contributes to the existing literature by focusing on the FX market and covering the sample period during five years after the introduction of euro. We also study the impact of sixteen macro indicators on the exchanger rates, and contribute to the existing literature by observing implied volatility behavior during five days prior to and following the announcement day. In addition to studying the asymmetric feature of the announcement effect in terms of the sign of the surprise element, which has already been done, we are one of the first to study the asymmetric impact of the announcements in terms of the magnitude of the surprise element. We also study the impact of the BOJ interventions and various features of this impact (e.g. the magnitude of the intervention, purchase/sale of the JPY) on the implied volatility of all the major exchange rates, to determine whether the intervention – volatility relation studied for the sample periods preceding euro changed with the adoption of euro.

Section 2.1.1 of this chapter examines the impact of news announcements on the implied volatilities in stock, interest and bond markets. In Section 2.1.2, we provide a summary of the announcement effect in the FX implied volatilities, which is more relevant for our empirical study. Section 2.1.3 differentiates between the impact of scheduled and unscheduled news announcements, discussing in detail, the effect central bank interventions have on the FX implied volatility. In section 2.1.4, we discuss the dynamic feature of the announcement effect and its dependence on the state of the economy, while in section 2.1.5, we examine the impact of US vs. non-US news on the FX implied volatility. Section 2.1.6 provides a summary and highlights contributions that our study will offer to the existing literature.

2.1.1. Announcement Effect in Non-FX Markets

The initial studies on the impact of news announcement on the volatility mainly focused on the equity and treasury markets. The first studies on the volatility patterns were conducted by Merton (1973) and Donders and Vorst (1996). Donders and Vorst (1996) observed an increase in the implied volatilities of stock options around the scheduled news announcement days and found implied volatility dropping sharply after the event day for few days. Using data from the U.S. treasury market, Fleming and Remolona (1997) concluded that the realized volatility is higher when scheduled macroeconomic reports are released. In contrast, Cutler et al. (1989) and Mitchell and Mulherin (1994) found little association between the US stock market volatility and readily identifiable economic news. Likewise, Berry and Howe (1994) reported no significant relation between US equity volatility and the total number of news releases by the Reuters News Service.

Sun and Sutcliffe (2002) studied the impact of nine macroeconomic variables on the spot, futures and options market in the UK short-term interest rates, concluding that MPC announcements lead to a substantial decrease in the implied volatility, RPI announcements result in a smaller decrease, while non scheduled announcements are associated with a small increase in the implied volatility. Nikkinen and Sahlstrom (2004) investigated the behavior of the implied volatility index VIX (implied volatility index of S&P100) around the employment, inflation reports, and the FOMC meeting days. They suggested that implied volatility increases prior to the scheduled news release and decreases after the announcement with the employment report being found to have the largest impact on the volatility, followed by FOMC meetings.

2.1.2. Announcement Effect in FX Markets

Most of the studies on the volatility announcement effect have been conducted on the US stock market and given that the majority of the US macroeconomic announcements are released early in the morning prior to the opening of the US stock exchanges, the studies on the equity volatilities may suffer from a lack of power. The FX market is 24 hour market, so the announcements occur while the markets are open. The FX market is the largest financial market in the world, while the recent developments (electronic trading, the introduction of the euro and new market instruments) have made FX one of the most challenging markets for researchers and practitioners. The relation between FX volatility and fundamentals has been explained by the different motives of the heterogeneous agents[1] (Farmer and Joshi, 2002), different trading strategies (Admati and Pfleiderer, 1988), psychological choices (Veronesi, 1999) and different abilities to forecast and analyse the impact of the new information on the value of the exchange rates (Damodaran, 1985).

There is already a sizeable literature on the effects of US public information releases on the FX market volatility. For instance, Ederington and Lee (1993) found that regular scheduled US macroeconomic announcements lead to significant time-of-the-day and day-of-the-week patterns in the volatility of USD/DEM FX futures and explained this relation by the private information arrival. Goodhart et al. (1993) made a study on GBP/USD rate using 12 weeks high frequency data and found that two specific news significantly impact the intraday currency volatility. Ito and Roley (1987) suggested that both US and Japan money supply and industrial production figures help to explain the movements in the Yen/Dollar exchange rate. Madura and Tucker (1992) analyzed the relation between currency option implied standard deviation (ISDs) and the surprise component of monthly merchandise trade deficit disclosures. They concluded that deficit disclosures, regardless of their content increase market uncertainty and that larger surprises, regardless of their sign are associated with increased currency implied standard deviations.

[1] The heterogeneous expectations concerning the fundamental value of an asset increase the volatility in the short run and the strategies of chartists increase the volatility in the long run

Low and Muthuswamy (1995) found a significant relationship between news arrival rate and DEM/USD and JPY/USD rate volatilities, while Melvin and Yin (2000) suggested that DEM/USD volatility varies positively with the total number of news items reported in Reuters News Service. DeGennaro and Shrieves (1997) concluded that USD/JPY volatility increases prior to the public announcements and declines significantly after the information release. Andersen and Bollerslev (2003) pointed that the announcement impact depends on its timing relative to other related announcements, and on whether the announcement time is known in advance. Chang and Taylor (2001) found a significant and symmetric impact of the German and US news on the DEM/USD volatility. The impact of German news on DEM/USD volatility was found to be longer lived than that of US news. The authors explained this phenomenon by the steady monetary policy followed by the Federal Reserve.

Andersen and Bollerslev (1998) found an evidence of an increased DEM/USD volatility related to the public news announcements. The most important US news having the biggest impact on the DM/USD exchange rate were real economy related indicators like gross domestic product, employment report, trade balance and durable good orders. The German announcements having the biggest impact on the DM/USD rate were found to be the monetary indicators like Bundesbank meetings and MP3 supply figures. Andersen and Bollerslev (1998) explained this phenomenon by the fact that the monetary policy of Federal Reserve System was stable, while the monetary policy of the Bundesbank was highly controversial.

After Kawaller et. al (1993) showed that futures markets tend to adjust more quickly to new information compared to spot markets, many papers focused on the behavior of the FX futures. Harvey and Huang (1991) explained significantly positive USD/JPY futures volatility during US trading hours by the release of US macroeconomic indicators, while Ederington and Lee (1993) and Leng (1996) found that the volatility of DEM/USD rate futures is significantly affected by the release of the macroeconomic news announcements. Kim et. al (2004) studied the impact of six

US macroeconomic indicators on JPY/USD and DEM/USD futures for the period from 1987 to 1998. They reported a significant impact of a trade balance and retail sales indicators on the currency volatility. The balance of trade announcement was found to cause an increase in DEM/USD volatility, while the release of the retail sales was found to cause an increase in JPY/USD volatility. After reporting low implied volatilities in the early part of the week and high volatility in the later part of the week from Wednesdays, Kim et. al (2004) suggested that when a scheduled macroeconomic announcement is made during the week, the implied volatilities remain unchanged or decline from the previous day. This is in line with the hypothesis that the uncertainty is resolved as information is released on the announcement days.

2.1.3. Scheduled vs. Unscheduled Announcements

It is generally believed that the unscheduled events tend to have stronger impact on the asset prices than the scheduled events. Dominguez and Panthaki (2005) argued that unscheduled news results in more ambiguous information that may lead stronger differences of opinion about the implications of the information, and therefore result in larger changes in the volatility. Andersen and Bollerslev (1998) found that the volatility shocks from the scheduled, expected news announcements tend to be short lived (since the timing of the news is already known in advance), while the unscheduled events cause prolonged changes in the volatility. Andersen and Bollerslev (1998) showed that three large and long-lived volatility increases are related to the Russian crisis and the stock market crash, the events that could not anticipated in advance. Although most studies focused on the scheduled announcements, some studies studied an impact of the unscheduled announcements on the market volatility: ten major news announcements (Cornell, 1978), takeovers (Barone-Adesi, Brown & Harlow, 1994), mergers (Jayaraman et al, 1991, Levy & Yoder, 1993), interest rate changes (French & Fraser, 1986), the effect of the Louvre Accord on volatility in currency markets (Tucker & Madura, 1991).

DeGennaro and Shrieves (1997) came to the conclusion that while scheduled news announcements and unscheduled interest rate reports cause volatility to increase, unscheduled news announcements are associated with the opposite effect, they cause the volatility to decrease. They found that after the scheduled news announcement volatility increases dramatically and remains at higher than normal level for about 10 minutes. After the interest rate announcements volatility also increases, but not as much as after the scheduled news announcements. Finally, a small but significant reduction in volatility was observed after the unscheduled news announcements for about 20 minutes. The researchers explained this phenomenon by the calming effect of such announcements or by the tendency of the announcements to be released during relatively calm times at the FX market.

2.1.3.1. Central Bank Interventions

The main objective of a central bank in conducting intervention is to minimize the deviations of the exchange rates from the pre-established targets and to dampen short term volatility (Neumann, 1984, Natividad and Stone, 1990 and Bhattacharya and Weller, 1995). A positive link between volatility and central bank interventions has been detected, regardless of the research method used to measure the volatility - univariate GARCH models (Baillie and Osterberg, 1997), implied volatilities (Bonser-Neal and Tanner, 1996 and Dominguez, 1998), and realized volatility (Dominguez, 2006). Although, intervention is likely to cause an increase in implied volatility by contributing to market uncertainty (Baillie and Humpage, 1992, Baillie and Osterberg, 1997 and Humpage, 2003), Ramchander and Sant (2002) argued that central bank intervention can reduce exchange rate volatility by giving a clear signal about future monetary policy and stopping speculative attacks against a currency.

Dominguez (2006) showed that the influence of central bank interventions on the FX market depends on the intraday timing of intervention operations, as well as whether the operations are coordinated with another central bank. The effect of the bank intervention also depends on the willingness of the bank to back up intervention by subsequent changes in monetary policy. Dominguez and Frankel (1993) found that actual announced US intervention had reduced conditional daily and weekly USD/DM and USD/JPY FX rate volatility over the 1985-1991 period, but 'secret' intervention had increased conditional volatility. A central bank could intervene in the FX market just as the response to the volatility conditions in the exchange rate market. This is consistent with the view that interventions are not conducted in a random way and tend to react rather to exchange rate developments (Kearns and Rigobon, 2004 and Neely, 2005). Beine et. al (2006) provided evidence that the coordinated interventions produce FX volatility jumps, but failed to find any evidence in favor of a causality where central banks jointly intervene in reaction to the occurrence of jumps.

Bonser and Tanner (1996) found that central bank intervention is associated with positive changes in the DEM/USD and USD/JPY implied volatilities during 1985-1991, and especially during the February 23, 1987 to December 31, 1989 Louvre Accord period. Federal Reserve intervention is associated with the negative changes in DEM/USD implied volatilities over the 1985 to February 1987 and 1990 to 1991 sub-periods, although the effect is significant only in the 1990 to 1991 sub-period. Bonser and Tanner (1996) explained this by market participants not expecting central bank intervention to reduce exchange rate volatility in 1985-1991 period. Ramchander and Sant (2002) studied the impact of the Fed interventions in 1985-1994 on the volatility of USD/DEM and USD/JPY futures contracts, arguing that since futures prices lead spot prices, the use of futures volatility improves the reliability of the results. Ramchander and Sant (2002) found a significant reduction in USD/JPY volatility after the Fed interventions (though the interventions conducted in 1990-1993 period are followed by the higher than normal volatility) noting that Fed is more actively involved in the FX market during periods of higher volatility. However, they did not observe any significant change in USD/DEM volatility after the Fed interventions. They attributed the difference in the results to the role each currency plays in the internal FX market and monetary system. Unusually high USD/JPY volatility in 1990-1993 could be explained by the breakdown of the Louvre accord that brought lower cooperation among central banks in coordinating intervention operations.

Harvey and Huang (2002) found that the FX futures volatility increases significantly during the Fed interventions, while Lu and Wu (2006) conducted similar study for the Australian case, finding evidence of the Australian central bank's interventions significantly increasing the volatility of both AUD/USD spot and futures markets. Both studies tried to explain this phenomenon by the fact that the market trying to infer the central bank's policy implications with uncertainty as to the Banks' behaviors and policy intentions. Harvey and Huang (2002) concluded that the when the central bank keeps its policy intention highly secret, the effects of the central bank interventions are limited, since they cause confusion among market participants as a result of their inability to identify the Bank's policy intentions.

2.1.4. Good Economy vs. Bad Economy

According to McQueen and Roley (1993), positive news about the economic activity (e.g. industrial production, GDP, capacity utilization) tend to cause an increase in the stock prices when an economy is weak, and a fall in the stock prices when an economy is strong. Andersen et. al (2003) provided evidence that bad news in good times (economic expansions) have greater impacts than good news in good times, suggesting that good news in good times confirms beliefs but bad news in good times comes as more of a surprise. The asymmetry volatility effect, as characterized by the bad news shocks leading to higher volatility than good news shocks has already been documented by Nelson (1991), Engle and Ng (1993), Glosten et. al (1993), Bekaert and Harvey (1997), Brooks and Henry (2000), and Bekaert et. al (2003). Most empirical studies explained this phenomenon by the increase in the amount of information following the announcement of bad news shocks, which also affects market participants' expectations.

Dominguez and Panthaki (2005) suggested that the influence of both scheduled and unscheduled news on exchange rates may be related to the state of the market at the time of the news arrival. Dominguez and Panthaki (2005) concluded that during periods of high uncertainty, as indicated by high volatility, and during periods of higher than normal news arrival, news have a significantly larger influence on the FX market than during normal periods.

2.1.5. US News vs. Non US News

Our objective is to examine the impact of US macroeconomic announcements only. Several papers studied an impact of news from different countries on the FX volatility and concluded that US news releases have stronger impact on the financial asset volatility than news coming from the rest of the world (Andersen et. al, 2003 and Nikkinen and Sahlström, 2003).

Almeida, Goodhar and Payue (1998) and Andersen et. al (2003) have documented the importance of US news over European news in terms of its impact on the currency market volatility. As indicated by Almeida, Goodhar and Payue (1998), these findings could be explained by the fact that US macro announcements are released on a regular time basis, while the timing of many macroeconomic news releases in Europe is not always known in advance. In addition, as suggested by Melvin and Yin (2000) and Laakkonen (2004), the type of the news announcements could also explain the importance of US news releases. The majority of US macro announcements, which have a significant impact on the market volatility, are the real economy indicators, such as employment report. As indicated by Andersen and Bollerslev (1998), the majority of the significant European indicators are those associated with the central bank's monetary policy, such as central bank meetings and MP3 supply figures. Given that recently, the monetary policy of ECB has not been very aggressive, in spite of the sluggish economic growth in Europe, the US news are more important in explaining FX volatility than European ones.

2.1.6. Summary

There is an existing literature on the announcement effect in the FX implied volatilities, which document a significant impact of the news announcements on the FX implied volatilities. The existing literature uses Reuters headlines, scheduled and unscheduled macro announcements, headlines of financial newspapers (Chan et. al (2001) as the proxy for the information flow. Implied volatility tends to increase prior to scheduled announcements and decrease following the announcements. The release of the unscheduled news announcements, such as interventions, was found to drive market uncertainty up, causing an increase in implied volatility. Announcement effect is also more pronounced for bad news and especially when the economy is weak.

The latest studies on the announcement effect cover the period prior to the introduction of Euro with only few extending beyond January 1999, when the euro was officially adopted as a single European currency. Our study contributes to the existing literature by focusing on the FX market and covering the sample period during five years after the introduction of euro. We also study the impact of sixteen macro indicators on the exchanger rates, and contribute to the existing literature by observing implied volatility behavior during five days prior to and following the announcement day. In addition to studying the asymmetric feature of the announcement effect in terms of the sign of the surprise element, which has already been done, we are one of the first to study the asymmetric impact of the announcements in terms of the magnitude of the surprise element. We also study the impact of the BOJ interventions and various features of this impact (e.g. the magnitude of the intervention, purchase/sale of the JPY) on the implied volatility of all the major exchange rates, to determine whether the intervention – volatility relation studied for the sample periods preceding euro changed with the adoption of euro.

2.2. CALENDAR PATTERNS IN THE FX RETURN SERIES

The presence of the seasonality patterns, such as day of the week effect in the financial asset returns has been well documented in the finance literature[2]. Although there is no shortage of the literature on the FX day of the week effect[3], the literature on other seasonalities is mainly limited to the equity markets. The study of various seasonality patterns, such as turn of the year, month of the year and holiday effects fills a gap in the existing literature on the FX calendar effects. Besides, the use of a sample period from January 1994 to December 2003 provides an opportunity to cover pre and post euro periods with the aim of identifying the impact of euro on the FX calendar anomalies.

In Section 2.2.1, we discuss a day of the week effect in the FX and non-FX asset return series and summarize theories that explain intraweek patterns. In Section 2.2.2, we provide a summary of other calendar patterns in the equity, bond and FX returns. Section 2.2.3 provides a summary and highlights contributions that our study will offer to the existing literature.

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[2] Solnik and Bousquet (1990), Chang et. al (1993) and Hiraki and Maberly (2003), among others, demonstrated day of the week patterns in the US and non US equity markets, while Corhay et. al (1995), McEwan (2002), Yamori and Mourdoukoutas (2003) and Yamori and Kurihara (2004) indicated that the return distribution of futures and cash FX markets also varies by day of the week. Many studies focused on other seasonality patterns in the stock and FX return series, such as January effect (Jones et. al, 1991 and Yamori and Kurihara, 2004), turn of the month effect (Wong, 1995, Aydogan and Booth, 1999 and Kunkel et. al, 2003), quarterly patterns (Cyr and Llewellyn, 1994), and holiday effect (Lakonishok and Schmidt, 1988, Ariel, 1990 and Aydogan and Booth, 1999).

[3] More recent studies on the FX intraweek patterns (Cornett et. al, 1995 and Aydogan and Booth, 1999) found evidence of the positive and statistically significant Tuesday and Wednesday and negative Thursday and Friday returns.

2.2.1 Day of the Week Effect in Return Series

Out of all seasonality patterns, the day of the week effect has received the most attention, while the equity market has been a focus of the majority of the publications. There is also a considerable literature on the dynamic feature of the intraweek patterns in the equity markets, suggesting that the day of the week effect is strongly related to the state of the economy. Besides, many papers focused on possible explanations for day of the week effect, including private information hypothesis and the announcement effect. In section 2.2.1.1 and 2.2.1.2, we discuss intraweek patterns in non-FX and FX return series, respectively. Section 2.2.1.3 examines the dynamic feature of the day of the week effect, while section 2.2.1.4 provides a summary of possible explanations for the day of the week effect.

2.2.1.1. Day of the Week Effect in Non-FX Returns

The majority of the studies on the day of the week effect focused on the weekend effect in the equity markets, indicated by abnormal returns on Fridays and Mondays. Keim and Stambaugh (1984), Jaffe and Westerfield (1985) and Harris (1986) reported a weekend effect in the equity markets, suggesting that rates of return on Monday tend to be significantly negative, and rates of return on the last trading day of the week (e.g. Friday) tend to be significantly positive. Dow Jones Industrial Average (US), Financial Times Index (UK), Nikkei Average Index (Japan), Hang Seng Index (Hong-Kong), Faz General Index (Germany) and All Ordinary Index (Australia) were all found to exhibit negative returns on Mondays and positive returns on Fridays (Cross, 1973, Board and Sutcliffe, 1988, Kohers and Kohers, 1995 and Tang and Kwok, 1997). The negative returns on Tuesdays rather than on Mondays that are observed mainly in the emerging markets (Wong et. al, 1992, Aydogan, 1994 and Balaban, 1995) are explained by the fact that it takes one day before the effect of the negative returns in US market arrives to other markets.

Lakonishok and Schmidt (1988) studied a weekend effect and came to the conclusion that the average Monday returns on DJIA index for the period of 90 years from 1897 to 1986 are significantly negative (-0.076), while the return on the last trading day (Saturday prior to 1952 and Fridays after 1952) are significantly positive. They also concluded that Fridays tend to have positive returns even when it was not the last trading day prior to 1952 (NYSE was open on Saturdays before 1952). High Friday returns could be explained by the release of the large amount of information on Fridays (Ederington and Lee, 1993 and Andersen and Bollerslev, 1998).

Connoly (1989) also found evidence of the day of the week effect, suggesting that the weekend effect is not stable over time- it appears in some periods, disappears in certain periods and reappears in others. Brusa et. al (2000, 2003) provide evidence of the reverse weekend effect in a recent period: Monday returns have become positive and larger than those on other days of the week. The reverse effect indicated by positive rather than negative (traditional effect) Monday returns that are larger than those on other days of the week was found over the recent period of ten years 1988-1998. Brusa et. al (2000, 2003) found the traditional weekend effect in the equity market to be related to small firms and reverse weekend effect to be related to the large ones. The return series in NASDAQ index, the index representing the smallest firms was found to display traditional weekend effect indicated by negative Monday returns in 1988-1998, the period when returns on other indexes representing larger firms exhibited reverse weekend effect. This observation led some researchers to conclude that the traditional weekend effect is explained by the high proportion of the individual investors relative to institutional ones (Lakonishok and Maberly, 1990 and Abraham and Ikenberry, 1994), and reverse weekend effect is explained by the high proportion of the institutional investors relative to individual ones (Brusa et. al, 2000). Another difference between traditional and reverse weekend effects is that during the early periods when Monday exhibited negative returns, Monday returns were positively related to Friday returns, while in a recent period characterized by the reverse weekend effect, Monday returns were positive regardless of whether Friday returns were positive or negative. Keim and Stambaugh (1984) obtained surprising results that led them to conclude that Monday effect is nothing more than the weekend effect, which is highly related to the January effect. The authors came to this conclusion after finding that Monday returns are positive during January and negative during the remainder of a year.

2.2.1.2. Day of the Week Effect in FX Returns

The evidence of the day of the week effect has also been reported in the FX markets (Hilliard and Tucker, 1992 , Cornet et. al, 1995 and Corhay et. al, 1995). McFarland et. al, 1982, Jaffe and Westerfield (1985), So (1987), and Cornet et. al (1995) found the returns on foreign currencies against USD to be generally high on Monday and Wednesday and low on Tuesday and Friday. Yamori and Kurihara (2004) reported negative Wednesday and positive Friday returns for the European currencies in the sample period of 1980s. Hilliard and Tucker (1992) compared the seasonality patterns in both spot and derivative FX markets, finding the returns on the spot exchange rates on all weekdays to be positive, while the returns on the put currency options to be negative.

Aydogan and Booth (1999) found an evidence of the day of the week effect in the Turkish FX market indicated by the significantly positive returns on Tuesdays and Wednesdays. Tuesday returns were found to be twice as large as the average daily return, and Friday returns were found to be the lowest. The effect was more pronounced in the period of 1990-1994 compared to 1986-1989. Aydogan and Booth (1999) explained the day of the week effect by treasury auctions and banks' management of liquidity. Berument et. al (2007) also provided an evidence of a day of the week effect in the Turkish currency markets, associated with high Thursday and low Monday returns. Using an extensive data set for six exchange rates, Corhay et. al (1995) provided an evidence of the higher Wednesday returns prior to October, 1981 for GBP, CAD, DM, CHF and JPY. According to Corhay et. al (1995), the effect disappear after October, 1981, because of the change in the settlement procedures that took effect in 1981. McEwan (2002) reported a weekend effect on the FX market, and calculated the rates of return obtained for ten exchange rates from the trading strategy designed to exploit the weekend effect: buy on Friday close and sell on Monday close. A trading strategy tested by McEwan (2002) generated a significant return for all exchange rates, but HKD/USD.

Cornett et. al (1995) conducted a study on the FX futures using the intraday data for the period of fourteen years. They found that during US non-trading period when the markets in Japan and Europe are open, the foreign currencies (from the perspective of the US investor) tend to weaken, and that during the US trading hours, they tend to strengthen. Cornett et. al (1995) found the evidence for the day of the week effect, mainly indicated by the significantly negative returns from Thursday close to the Friday open[4]. After dividing the close-to-close daily returns into the overnight and intraday returns from the perspective of the IMM, Cornett et. al (1995) came to the surprising conclusion that the day of the week effect is mainly attributable to the overnight returns, returns generated when the IMM market is closed.

2.2.1.3. Dynamic Feature of the Day of the Week Effect

As pointed out by Hiraki and Maberly (2003), the seasonality patterns are not stationery but dynamic. The existing literature provides evidence of the return anomalies in the financial markets in the 1970s and 1980s, but shows that patterns disappear after early 1990s. Wood (1994) investigated day of the week, pre- and post-holiday, turn of the year, turn of the month, and month of the year effects in Pacific Rim and US markets before and after 1987's crash. He found that seasonality patterns declined significantly after the crash. According to Wood (1994), alteration of the return generation process in these markets indicated by the doubled volatility in six month following 1987 crash (Leland and Rubinstein, 1988) is the most likely cause of the change in the return patterns. Yamori and Mourdoukoutas (2003) concluded that the flattening of the FX pattern in the USD/JPY FX rate is due to the financial deregulation in Japan. Yamori and Kurihara (2004) confirmed that the

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[4] This is not consistent with the results obtained for other asset categories and especially for the equity markets, where the weekend overnight returns or specifically the return from the Friday close to the Monday open tend to be negative and the largest in the absolute terms (French, 1980 and Harris, 1986).

anomalies observed in the return series of the exchange rates of the US dollar to the European currencies in the 1980s disappeared in the 1990s.

For the Greek market, Alexakis and Xanthakis (1995) found negative returns on Tuesdays, significant positive returns on Fridays, and insignificantly positive returns on other days of a week for a period of 1985-1994. For the period of 1989-1995, Nikou (1997) found negative returns not only on Tuesdays, but also on Wednesdays. Finally, for the most recent period of 1994-1999, Lyroudi et. al (2002) found negative returns on Thursdays and significantly positive returns on Fridays, Wednesdays and Mondays. Condoyanni et. al (1987) studied the French stock market returns for the period of 1969-1984 and reported significant negative returns on Tuesdays and significant positive return on Thursdays. Solnik and Bousquet (1990) confirmed the negative returns on Tuesdays for the period of 1978-1987, and found positive returns on Fridays. Dubois and Louvet (1996) covered the period of 1969-1992 and found negative returns on Monday and the highest return on Wednesdays for the French, UK, US, German and Swiss markets. Finally, Lyroudi and Angelidis (2003) covered the period of 2000-2003 and found the lowest returns on Wednesday and high returns on Thursday. However, neither returns were found significant, indicating that the day of the week pattern in the French stock flattened in the first years of this decade. Although Wednesday negative returns were not found to be significant, the findings are interesting, since negative Wednesday returns were observed not only in the French stock market, but also in other European markets like Germany, Netherlands, Spain, Sweden and UK (Lyroudi and Angelidis, 2003). These findings show that the patterns in the asset returns tend to change and it would be interesting to undertake a study on the asset return patterns for the recent periods.

There is an evidence that the day of the week or specifically a weekend effect is more pronounced in the declining markets. Board and Sutcliffe (1988), Chang et. al (1993), Fishe et. al (1993) and Arsad and Coutts (1997) showed that the direction of the market is the important variable in determining the weekend effect. They provided the evidence that the weekend effect is not pronounced when the stock market rises. Steeley (2001) suggested that the weekend effect had disappeared in the UK stock market in the 1990s. Besides Steeley (2001), and Aggarwal and Tandon

(1994) showed the weakening of the day of the week effect. However, Steeley (2001) showed that the weekend effect reappeared after the direction of the market was taken into account. Steeley (2001) found that the negative returns on Mondays and Fridays are significantly different from the returns on other days of the week, when only negative returns were considered. This pattern was not observed when only positive returns were taken into account. The weekend effect was even more pronounced when the days with negative returns and with the news announcements were considered. The weekend effect flattened when the non-announcement days with the negative returns were studied. Finally, although no weekend effect was observed for the days with the positive returns, a day of the week effect reappeared when the announcement days with positive returns only were taken into account. These findings are the evidence of the fact that the market direction explains the day of the week effect.

2.2.1.4. Explanations of the Day of the Week Effect

There is no theory that fully explains the anomaly in the financial markets. Private information hypothesis, announcement effect, measurement errors are only few of numerous explanations provided by the academic literature. In this section, we discuss various theories and hypothesis that explain day of the week effect in the FX and equity return intraweek patters.

2.2.1.4.1. Private Information Hypothesis

The most accurate explanation is given by the private information hypothesis by Admati and Pfeiderer (1988) and Foster and Viswanathan (1990). The theory suggests that Monday open trading reflects the impact of the negative information accumulated during the weekend. According to Admati and Pfeiderer (1989), the market makers avoid the cost of trading with informed traders by buying, for example, only on even numbered days and selling only on odd-numbered days. This order imbalances explain the day of the week effect. This theory was later supported by Poter (1992) who conducted a study on the US and Canadian markets. However, Admati and Pfeiderer (1989) hypothesis does not explain a day of the week effect in the European markets (Chang et. al, 1993).

According to Lakonishok and Maberly (1990), Abraham and Ikenberry (1994) and Chang et. al (1995) a negative Monday returns are due to the individual trading that dominate more on Mondays than on any other day of the week. They suggested that since individual selling dominates individual buying, the concentration of the individual traders on Mondays may cause more noise trading on Mondays than on other weekdays[5]. Damodaran (1989) suggested that most firms release negative information about earnings and dividends on weekends after the market closes on Friday. On Monday the market responds, causing abnormal negative returns on Mondays. In contrast, Damodaran (1989) concluded that the news arrival patterns explain a small part of the US day of the week effect.

FX market is different from the stock market in a way that it is 24 hour OTC market. Therefore, when the US market opens on Monday, the Asian markets would have already been closed for a day and London and other European markets are midway through the trading day. So, if the private information hypothesis is true, the informed traders should take advantage of the private information after the Asian and specifically Japanese markets open on Monday. However, private information theory also explains day of the week effect in the FX return series. Cornet et. al (1995) found that the FX market exhibits negative returns in close to open returns on Fridays, not on Mondays that would indicate the equity weekend effect[6]. As it has already been discussed, the private information theory suggests that Monday open trading reflects the impact of the negative information accumulated in the markets during the weekend. Cornet et. al (1995) study was from the US investor's perspective, so technically they could not observe the weekend effect and could not test Admati and Pfeiderer's (1988) and Foster and Viswanathan's (1990) private information hypothesis. In order to find the weekend effect, one should look at the FX prices at the open of the Asian markets not the US market. But the private

[5] This hypothesis was later supported by Chang et. al (1998).
[6] This result could be explained by the market structure of the FX market and by the private information hypothesis of Admati and Pfeiderer (1988) and Foster and Viswanathan (1990).

information theory explains significantly negative returns from the Thursday close to the Friday open. There is only one non-trading period during the week that is followed by the opening of the US market (IMM). This period is 1 hour 20 minutes period prior to the IMM opening at 7:20 CT, when the European markets close earlier than on previous days of a week: at 6:00 CT. This time gap is sufficient for the informed traders to take advantage of the private information accumulated during the non-trading time, which causes large negative close to open returns on Friday US morning.

2.2.1.4.2. Announcement Effect

The seasonality patterns could also be, at least partially, explained by the announcement effect. Steeley (2001) proved that for the days in the UK stock market when the prices were falling, the weekend effect indicated by significant negative returns on Monday disappears when the impact of the news announcements is taken into account[7]. Given that a large amount of the US macroeconomic announcements is released on Thursdays (e.g., money supply) and on Friday mornings (e.g., unemployment, producer price index, capacity utilization), significant Thursday and Friday returns in the FX markets could be explained by the announcement effect (Harvey and Huang, 1991). Yamori and Kurihara (2004) suggested that since anomalies are observed only for limited number of the currencies traded in the US FX market, US news announcement do not fully explain day of the week effect.

2.2.1.4.3. Transactions Hypothesis

Cornet et. al (1995) tried to explain the intraweek patterns in the FX returns by the transactions hypothesis. It is known that the transactions between countries and multinational corporations involved in the international trade are settled in the home or exporting country's currency. Both US and non-US importing firms buy the foreign currency that they use in the international transactions to buy foreign goods during their own business hours. Therefore, the US firms buy foreign currencies for

[7] This would indicate that the announcement effect explains the weekend effect.

US dollars during US trading hours, which causes the strengthening of the foreign currencies against the US dollar. The foreign firms buy US dollar for their own currencies, which are considered to be foreign from the perspective of US during their own business hours (US non trading hours), causing the strengthening of the US dollar and weakening of the foreign currencies. The researchers explained significantly negative returns from Thursday close to the Friday open by the behavior of the dealer and speculators. Foreign importing firms buy US dollars to pay for the US goods whose price is quoted in US dollars. Non-US dealers and speculator who sell US dollars and keep long positions in foreign currency are exposed to the additional risk associated with the release of several important US macroeconomic indicators. To avoid this risk, the dealers offload the long positions in the foreign currency during non-US trading session, just before the US markets open. This causes a significant fall in the value of the foreign currencies. High returns during the first hour and during the last two hours is explained by volume. During the first hour at IMM, informed traders trade heavily along with the liquidity traders an make the adjustments to their positions, which is indicated by high tick volume at IMM. After the first hour, the US volumes decline, while other markets and specifically London market continues to trade heavily. Heavy trading during European sessions, where investors buy US dollars and sell foreign currencies causes negative returns in the foreign currencies. After the European markets are closed, the US market remains the only open market, and therefore the net buyers of the foreign currency causes the foreign currencies to increase in value against the US dollar.

2.2.1.4.4. Settlement Effect

At the financial markets, most transactions are settled several business days after the quote or transaction date[8]. Gibbons and Hess (1981) tried to explain the day of the week effect by the fact that the asymmetry in the settlements periods caused by the settlements days being not always the same in the long run, affects the exchange rate returns. Agrawal and Tandom (1994) categorized 18 stock markets with the same settlement days into groups expecting to see similar patterns for stocks markets

[8] In the FX market, the time period between transaction and settlement dates is two business days.

in each group. Both Gibbons and Hess (1981) and Agrawal and Tandom (1994) failed to find any evidence that the settlement effect fully explains day of the week effect. To study the day of the week effect in 29 foreign currencies, Yamori and Kurihara (2004) hypothesized that since the transaction or clearing system is basically the same across the currencies, the settlement mechanism would explain the day of the week effect if all currencies display similar patterns. After finding the evidence of the day of the week effect for only some currencies in the period of 1980s, Yamori and Kurihara (2004) concluded that the transaction mechanism alone cannot explain the anomaly.

2.2.1.4.5. Spillover Effect

Jaffe and Westefield (1985) originally tried to explain a day of the week effect by the geographic proximity of the markets. They found high correlation between US and Canada markets, believing that US stock market anomalies might contribute to the patterns in the Canadian stock market. Agrawal and Tandon (1994) found the correlation between US stock indices and Asian stock market indices, and stated that US stock return anomalies cause day of the week effect in the Asian stock markets. Wood (1994) found negative Monday returns for US equity market and negative Tuesday returns in the Pacific Rim equity markets, which might indicate that negative returns on Tuesdays in the Pacific Rim is explained by the negative Monday returns spilling from US. Choudhry (2000) reported spillover effect from Japanese to two other Asian markets.

2.2.1.4.6. Investors' Psychology

Jacobs and Levy (1988) believed that investor psychology could explain day of the week effect in the financial markets. Most investors and traders consider Monday to be the worst day and Friday to be the best. As the result, traders prefer to buy on Fridays, which causes increase in demand. After the markets close for a weekend and then reopen on Monday the market returns to equilibrium, and the prices decline. The findings by Prince (1982) and Rogalski (1984) provide some evidence for this theory.

2.2.1.4.7. Measurement Errors

An existence of the day of the week effect or any other return anomaly could be caused by the measurement errors due to the noise factor and data snooping. Keim and Stambaugh (1984) suggested that the day of the week effect could be due to the systematically biased Friday returns, but failed to find any evidence. Lo and MacKinlay (1988) suggested that a degree of error caused by data-snooping[9] can be expected to increase with the number of studies published on the topic. Data with outliers (for example data covering the period that includes October 1987) is more prone to data snooping problem. Both Cross (1973) and French (1980) mentioned in their papers that their studies were motivated by the traders claiming that prices tend to fall on Mondays. Levi (1988) pointed out that Cross's (1973) studies of Monday effect covered the period of 1969-1972, the period with particularly large number of significant Monday returns.

[9] which means that the same data has been used in all previous works

2.2.2 Other Seasonality Patterns in the Return Series

Besides the day of the week effect, other seasonality patterns studied in the academic literature include January effect, turn of the month / year effects, quarterly patterns and holiday effect. In this section, we discuss findings on these calendar effects, the majority of which focuses on the equity market. Section 2.2.2.1 examines intra monthly patterns, mainly focusing on the turn of the month effect. In section 2.2.2.2, we discuss monthly patterns, including turn of the year and January effects, while in section 2.2.2.3, we focus on the holiday effect. Finally, section 2.2.2.4 summarizes quarterly effect.

2.2.2.1. Intra Monthly Patterns

Merrill (1966), Hirsch (1979) and Fosback (1976) were the first to suggest that equity returns are unusually high in the first half of a month. Ariel (1987) conducted a first well-known study on within-month seasonality patterns in the stock market focusing on nineteen years period of 1963-1981. Ariel (1987) obtained surprising results that the positive returns at CRSP index occur during the first half of each month[10]. The highest half-month returns were generated in the first half of April and especially in the second half of December[11]. Wood (1994) also obtained similar results for Taiwan and Australia, but opposite results (positive returns in the second half of a month) for Japan and Singapore. After trying to explain this phenomenon by a mismatch between calendar and trading time, a dividend effect, and a manifestation of the January effect, Ariel (1987) didn't find any empirical explanation. Using the data sample for seventy years, Lakonishok and Schmidt (1988) concluded that the returns in the first half of a month are not significantly different from the return in the second half of a month. The difference in the results obtained by Lakonishok and Schmidt (1988) and Ariel (1987) is explained by the characteristics of a period used by Ariel and mainly by the fact that Ariel's definition of the first half of a month included the last trading day of the previous month.

[10] Ariel (1987) reported 0.826% return during the first half of a month, while the rate of return during the second half of a month was only –0.182%.
[11] Significant positive returns in the second half of December are probably due to the holidays.

Jaffe and Westerfield (1989) found evidence of the monthly patterns in Australia, United Kingdom and Canada being similar to those in US markets and in Japan being inverse relative to US. Agrawal and Tandon (1994) also showed that the turn of the month effect had existed in the international markets in the 1970s, but suggested that this effect has faded in the 1980s. Cadsby and Ratner (1992) found a turn of the month effect in six out of ten countries they studied for the period of 1962-1989. The authors concluded that the observed intra-month pattern is not driven by the US market seasonality patterns, turn of the year effect and quarterly window dressing by the portfolio managers. Boudreaux (1995) found a monthly effect in the equity markets of eight European and Asian countries indicated by the significantly positive returns in a beginning of each month. Boudreaux (1995) conducted the tests after excluding January returns in order to test whether a monthly effect is the famous January effect[12], and found that although monthly effect weakened after excluding January returns, the results tend to be significant even when January was isolated. In contrast, Cadsby and Ratner (1992) did not find a turn of the month effect in Japan, Hong-Kong, Italy and France (for the period of 1962-1989), while Lee et. al (1990) did not find any evidence of the turn of the month effect for five Pacific Rim and two US stock indices. No turn of the month effect was found in Hong-Kong, Malaysia, Singapore, Taiwan and Thailand (Wong, 1995), and in the Turkish market (Balaban and Bulu, 1996).

Ariel (1987) also provided evidence for the turn of the month effect. He showed that the stock returns are particularly high in the last trading day of a month. Lakonishok and Schmidt (1988) confirmed these results suggesting that the returns generated during the last trading day of a month and during the first three days of the next month (0.473) exceeds not only the rate of return generated during the average four days period (0.0612), but also monthly price increase (0.349). Compton (2002) confirmed significant turn of the month effect in the US, Canada and Pacific Rim markets for the period of 1988-1998, after finding that 95% of the monthly returns could be explained by the returns generated during the last and first three days of a

[12] January effect is traceable to larger returns occurring early in the month (Keim, 1983 and Reinganum, 1983)

month. Compton (2002) also found that the turn of the month effect is fading in the US and Canadian markets, but is gaining strength in the markets of Pacific Rim (Australia, Japan, Hong-Kong and Singapore). Hensel and Ziemba (1996) confirmed these results where the turn of the month was defined as the last two and first three days of a month. Ziemba (1991) found a turn of a month effect in Japan that runs from –5 to +2 days of a month. Kunkel et. al (2003) examined 19 country stock market and found that the turn of the month effect is persistent for 16 countries and is not simply a spillover from the US market. Kunkel et. al (2003) also concluded that the turn of the month effect is not fully explained by the January effect, which contradicts Pearce (1996), but confirms the findings by Jordan and Jordan (1991), Pettengill and Jordan (1988) and Boudreaux (1995).

The study of the turn of the month effect has been extended into other financial markets. Jordan and Jordan (1991) did not find any evidence of the turn of the month effect in the US bond market, while Chang (1988) reported turn of the month effect in the commodities spot and futures indexes. In the FX market, Liano and Kelly (1995) found a limited evidence of the turn of the month effect for GBP and JPY FX futures. However, according to Liano and Kelly (1995), this turn of the month effect is indicated by the average daily rates in turn of the month days being significantly higher than those in non-turn of the month days for JPY and lower for GBP. No significant evidence of the turn of the month effect was found in Deutsche Mark or CHF futures. In the Turkish FX market, Aydogan and Booth (1999) found negative returns in the last week of a month and significantly positive returns in the first week of a month. A steady decline in daily returns from the beginning to the end of a month was observed. These findings imply that that the turn of the month effect is not unique to the stock market. Aydogan and Booth (1999) explained turn of the month effect in the Turkish FX by the currency substitution and cash disbursement patterns. Penman (1987) suggested that turn of a month effect could be due to a tendency of firms to announce good news during the first half of the month and bad news during the second half. Stewart (1987) explained this turn of a month effect by pension fund managers concentrating their buying at the end of the month to avoid a downward bias in estimated rates of return. Other explanation for the time of the month effect are dividend effect (for equity market), economic and political announcements dates concentrated in one part of the month and large market declines occurred during late October of the study period.

2.2.2.2. *Monthly Patterns*

The January effect has been reported in the financial markets (mainly stock markets) indicated by the statistically significant January return relative to other months (Schultz, 1985, Jones et. al, 1987 and Jones et. al, 1991). The January effect has been reported mainly for the stock market, and specifically for the small companies (Reinganum, 1981 and Keim, 1983). Keim (1983) also found that significant January returns for small firms tend to accumulate mainly in the first week of January. Roll (1983) found that January effect is mainly due to the abnormal returns accumulated during the last day of December and first four days in January. January returns for large companies' stock were not found to be significant (Lakonishok and Schmidt, 1988).

Roll (1983), Lakonishok and Schmidt (1984) and Howe and Wood (1993) reported high rates of return for large companies on the last trading day of the year (0.61 percent) and around Christmas. Lakonishok and Schmidt (1988) showed that the pre-holiday returns significantly exceed holiday and post holiday returns. They showed that this is especially true with December returns. The researchers showed that high end of December returns are due to the high returns on December 31st and December 24th. Rate of returns for the period four days after Christmas until December 31st was also found to be more important in explaining high end of December returns. The authors explained the observed phenomenon as the turn of the year effect where the returns generated in the last trading days of December and during the first trading days of January are significantly positive. Jacobs and Levy (1988) tried to explain turn of the year effect in the equity markets by annual bonuses, holiday gifts, and year-end pension contributions.

Roll (1983) and Tinic and Barone-Adesi (1983) explained a January effect in the stock market by the tax loss selling at the end of the fiscal year. Roll (1983) and Reinganum (1983) showed that small firms are affected by tax selling more than large firms, but Gultekin and Gultekin (1983) suggested that January effect observed in several equity markets cannot be attributed to a size related anomaly. The tax-loss selling hypothesis argues that there is a downward pressure on the prices of those stocks, which have declined during the year as investors attempt to realize their losses against their taxable income. After the end of the tax-year, price pressure disappears and the prices reach equilibrium level. Thus abnormally large returns are observed in the turn of the tax year. Jones et. al (1991) showed that January effect appeared in US only after 1917 when a personal income tax was introduced. The tax loss-selling hypothesis is also supported by the findings that in UK, April, which is the last month in a tax year, has significantly positive returns that are higher than returns generated during other months (Arsad and Coutts, 1996 and Baker and Limmack, 1998). Baker and Limmack (1998) showed that April was characterized by significantly positive returns only in the period of 1956-1967, and after 1967, the April effect in UK was replaced by January effect. Pandey (2003) found a January effect and significant March returns for Indian stock market index and given that March is the end of tax year in India, explained this by a tax loss-selling hypothesis. However, there exists a literature showing that tax-loss selling hypothesis does not predict seasonality effect. Brown, et. al (1983) and Gultekin and Gultekin (1983) showed that July is not characterized by significantly positive returns in Australia, the country that has June-July tax year[13]. Mills and Coutts (1995) found evidence that in UK positive returns are observed in January, not in April, while Draper and Paudyal (1996) found positive returns both in January and in April. This clearly indicates that tax loss hypothesis only partially explains monthly seasonality.

Chan (1985) and Debont and Thaler (1985) suggested that the monthly seasonality could be explained by an over-reaction effect with positive January returns persisting for a number of years following previous poor performance. Baker and Limmack (1998) confirmed these results finding that companies that experienced

[13] Gultekin and Gultekin (1983) found December returns to be significantly positive compared to other months

the worst performance in previous time periods earn returns in the following January, which are higher than those of other companies. Among other explanations of the January effect are the seasonal patterns in the release of information (Rozeff and Kinney, 1976 and Penman, 1987), a seasonal pattern in flow of funds from financial institutions, which leads to buying pressure on certain months of a year (Ariel, 1988), a pressure on fund managers to remove poorly performing securities before end-of-year scrutiny by trustees (Givoly and Ovadia, 1983 and Clare et. al., 1995).

2.2.2.3. Holiday Effect

Fosback (1976) noted that the S&P500 index displays high pre-holiday returns, while Lakonishok and Schmidt (1988) found the pre-holiday rate of return (0.220) to be significantly higher than average daily rate of return (0.0094). They explained this phenomenon by the fact that pre-holiday days are regarded as pre-weekend days (Fridays), but since pre-holiday returns are two-five times larger than pre-weekend returns, there appears to be some additional factor. The average post-holidays rate of return was found to be negative, but not significantly different from zero (confirmed by Ariel, 1990, Howe and Wodd, 1993 and Wood, 1994). Ariel (1990) failed to find any evidence that the pre holiday effect is caused by the additional risk around pre holiday days, the bias in bid –ask spread and the manifestation of other calendar anomalies. Lakonishok and Levy (1982) found that a change in settlement period caused by an exchange holidays does not explain holiday effect. Finally, Jacobs and Levy (1988) tried to explain high pre-holiday returns by the investor psychology and investor behavior. Liano et. al (1992) found that other documented calendar anomalies such as the turn-of-the year effect, the monthly effect, or the day-of-the-week effect do not cause the pre-holiday effect.

Cadsby and Ratner (1992) showed that pre-holiday effects exist in a number of international markets, and concluded that the pre holiday effect is not unique to the US market. Ziemba (1989) found evidence of a significant pre holiday effect in the Japanese stock market, while Wong et. al (1990) reported higher return in the equity markets of Malaysia, Singapore and Hong Kong prior to Chinese New Year holidays. Tan and Tan (1998) found that the holiday effect weakened for the Singapore market in the period of 1975 – 1994. Cadsby and Ratner (1992) found a significant pre holiday effect for US, Canada, Japan, Hong Kong and Australia with reference to their own local holidays, but mentioned that only Hong Kong exhibits a significant US pre holiday effect when US holidays only are considered. Chong et. al (2005) provided a strong evidence of a pre holiday effect in the Hong Kong and the UK equity markets, and marginally significant evidence of a pre holiday effect in the US. A pre holiday effect has also been documented in the equity markets of UK (Kim and Park, 1994, Mills and Coutts, 1995 and Arsad and Coutts, 1997), Japan (Kim and Park, 1994), India (Arumugam, 1999) and Greece (Coutts et. al, 2000). Liano et. al (1992) and Wilson and Jones (1993) also documented high returns on pre holiday trading days in the over the counter (OTC) stock markets, while Fabozzi et. al (1994) found evidence for a significantly higher pre holiday return in futures contracts for the period from 1969 to 1989.

In the FX market, Aydogan and Booth (1999) found a pre-holiday effect indicated by negative returns. They found that DM tends to appreciate against Turkish lira, while USD does not change significantly. This implies that DM tends to appreciate against USD on days just prior to holidays. Aydogan and Booth (1999) explained this effect by cash disbursement patterns and currency substitutions. As people living in US and other countries who tend to save money in USD go on holidays, they have to exchange US dollars into EUR, GBP and CHF. Aydogan and Booth (1999) mentioned that in the Turkish market, DM is the preferred foreign currency for wage earners who are engaged in currency substitution behavior (in 1994, 70% of FX deposits by Turkish residents were denominated in DM). The necessity for US residents and people who tend to save money in US dollars, to convert their money back to US dollars after holidays can partially explain the negative post holiday return. Contrary to Aydogan and Booth (1999), Liano (1995) examined a pre holiday effect in the currency futures market for the period of June 1977 – December 1992, and after finding no evidence of the pre holiday effect, concluded that the pre holiday effect is unique to the stock market.

2.2.2.4. Other Patterns

Other seasonality patterns covered in the existing literature include holiday effect and quarterly patterns. Penman (1987) compared the rates of return in the first 10 days of each quarter to the return series generated during other days. Cyr and Llewellyn (1994) found a little evidence of the quarterly seasonalities after controlling for outliers, serial correlation and multicollinearity.

2.2.3. Summary

The existing academic literature on the seasonality patterns mainly covers the day of the week effect. The initial studies provided evidence of the weekend effect in the US equity returns, indicated by low Monday returns. More recent studies on the FX intraweek patterns (Cornett et. al, 1995 and Aydogan and Booth, 1999) found evidence of the positive and statistically significant Tuesday and Wednesday and negative Thursday and Friday returns. Besides the findings of the day of the week effect, there is evidence of high equity returns in the first half of a month (compared to the second half), at the end of a month, beginning of the quarter, on pre holiday days and in January. Limited studies on the FX return anomalies (Liano and Kelly, 1995 and Aydogan and Booth, 1999) found evidence of the turn of the month and pre holiday effects.

Although there is some, though limited, literature on the day of the week and the turn of the month effects in the currency returns, the existing literature on other seasonality patterns is limited to the equity markets. The study of various seasonality patterns, such as turn of the year, month of the year and holiday effects fills a gap in the existing literature on the FX calendar effects. Besides, the use of a sample period from January 1994 to December 2003 provides an opportunity to cover pre and post euro periods with the aim of identifying the impact of euro on the FX return anomalies.

2.3. CALENDAR PATTERNS IN THE FX IMPLIED VOLATILITIES

The focus of most papers on the FX implied volatility seasonalities has been day of the week effect[14], while the existing literature on other seasonality patterns is limited to the equity markets[15]. The academic papers on the intraweek seasonality patterns in the currency implied volatilities (Ederington and Lee, 1996 and Kim and Kim, 2004) tend to focus on the FX futures, as opposed to FX cash markets. The coverage of the FX cash market and the study of various seasonality patterns, such as turn of the year, month of the year and holiday effects fills a gap in the existing literature on the FX calendar effects. Besides, the use of a sample period from January 1994 to December 2003 provides an opportunity to cover pre and post euro periods with the aim of identifying the impact of euro on the FX volatility patterns.

Section 2.3.1 examines a day of the week effect in the implied volatility, while section 2.3.2 focuses on other patterns in the implied volatilities. Section 2.3.3 provides a summary and highlights contributions that our study will offer to the existing literature.

[14] Existing literature on the day of the week effect in the equity implied volatilities found evidence of high implied volatility in the beginning of the week that tends to fall as a week progresses. In contrast, the FX volatility was found to be low on Monday and high on Thursday and Friday. Among numerous explanations for the day of the week effect documented in the academic literature, private and public information hypothesis are more common.

15 Several papers have been published on the holiday, turn of the year and turn of the month effects in the equity volatilities. There is also an evidence of significantly different equity and commodity volatilities in January, September, November and December.

2.3.1. Day of the Week Effect in Volatilities

Although, most papers focused on the return anomalies, day of the week effect in the market volatility has become a popular topic in the past two decades. Harvey and Huang (1991), Berument and Kiymaz (2001) and Sundkvist and Viskstrom (2000) studied day of the week effect in the stock and FX market volatilities. In section 2.3.1.1 and 2.3.1.2, we discuss intraweek patterns in non-FX and FX volatilities, respectively. Section 2.3.1.3 provides a summary of possible explanations for the day of the week effect.

2.3.1.1. Day of the Week Effect in Non-FX Volatilities

Harvey and Whaley (1992) found that S&P100 implied volatility tend to fall on Friday and rise on Monday. Although the results reported by Harvey and Whaley (1992) are not statistically significant, they become significant at 10% significance level, when the outliers associated with the October 1987 stock crash is excluded. Harvey and Whaley (1992) tried to explain this phenomenon by the traders' trading patterns. Since, many traders close their positions before the weekend, increasing selling pressure causes a significant fall in the implied volatility on Friday. As traders reopen their positions on Monday, a buying pressure causes the implied volatility to rise. Fleming et. al (1998) carried out similar study on the CBOE Market Volatility Index (VIX), which is the average of S&P 100 option (OEX) implied volatilities, finding no evidence of the significant day of the week effect for the implied volatilities calculated using trading days. Only Friday close to Monday close volatility was found to be significantly negative for the data set excluding the October 1987 outliers. After recalculating implied volatilities using calendar days, and observing significant increase in the volatility on Monday and significant decrease on Wednesday and Friday, Fleming et. al (1998) concluded that the day of the week effect reported by Harvey and Whaley (1992) is due to the fact that calendar instead of trading days were used to compute implied volatilities. Volatilities calculated based on the calendar days assume that the time to option expiration is measured in calendar days, which implies that the variance over a weekend is three times greater than volatility over a typical trading day (French, 1984). Since Friday to Monday stock market volatility has empirically been shown to be only marginally greater than typical trading day volatility (French and Roll, 1986), the adjustment of the implied volatility to a trading day basis is likely to produce more accurate results. Sundkvist and Visktrom (2000) suggested that the difference between using trading and calendar days is minimal with longer maturity options, but is increasingly important with the shorter maturity options.

Berument and Kiymaz (2001) used the S&P 500 index data to provide an evidence of the significant differences in stock market volatility across the days of the week, with the highest volatility observed on Friday. Sundkvist and Viskstrom (2000) studied German stock options market and found the implied volatility on Thursday to be somewhere higher and displaying patterns different from other days of the week. Kiymaz and Berument (2003) conducted a study on the day of the week effect at the stock markets of Canada, Germany, Japan, UK and US for the period of 1989-1997. They found significantly high volatility on Mondays for Canada, Germany and Japan, and significantly high volatility on Fridays for UK and US. According to Kiymaz and Berument (2003), high Friday volatility can be explained by the important news release on Thursday and Friday mornings in US (Harvey and Huang, 1991 and Ederington and Lee, 1993). By observing a drop in volume on Monday, Kiymaz and Berument (2003) explained high volatility on Monday for Canada, Germany and Japan by Foster and Viswanathan (1990) model, which suggests that the high volatility would be accompanied with low trading volume due to unwillingness of liquidity traders to trade in periods where the prices are more volatile. The lowest volatility was observed on Wednesday for Canada, on Tuesday for Germany, Japan, and UK, and on Monday for US. Tanizaki (2004) also reported increased volatility on Monday at the Japanese equity market, explaining it by the positive correlation between the amount of information and volatility, and the fact that Monday is followed by a non-trading period of two days, during which a large amount of information is accumulated.

Yalcin and Yusel (2003) studied the day of the week effect in the volatilities of 24 emerging stock markets. They found an evidence of the day of the week effect for 15 markets. However, in their later study, Yalcin and Yusel (2006) found an evidence of the day of the week effect in the stock markets of only 5 out of 20 emerging economies. Volatility was found to be the highest on Monday and lowest on Tuesday and Friday. Van der Sar (2003) reported high Monday volatility in the Dutch equity market and explained the results by a considerable release of unfavorable information on a delayed basis, following a weekend, induced by strategic and behavioral factors incompatible with the risk-return paradigm. Chukwuogor – Ndu (2006) used standard deviation of the equity returns as the proxy for the market volatility to study day of the week effect in 15 European financial markets. Chukwuogor – Ndu (2006) reported volatility to be skewed to the left and Monday to be the most volatile day for eleven markets. The financial markets of Russia, Turkey and Spain were found to be the most volatile, while Thursday and Friday was found to be extremely volatile days in few countries. Kenourgios (2006) reported strong day of the week effect in the volatility of the Greek equity market for the sample period of 1995-2000, indicated by significantly high volatility on Monday and Friday and low volatility on Tuesday. However, Kenourgios (2006) did not find any evidence of the day of the week effect for the sample period of 2001 – 2004, suggesting that the volatility patterns might have lost its significance due to the entrance of Greece into EU and stock market becoming more efficient.

2.3.1.2. Day of the Week Effect in FX Volatilities

Harvey and Huang (1991) provided an evidence of the day of the week effect in the volatility of the currency futures traded on the Chicago Mercantile Exchange's (CME) International Monetary Market (IMM). Using chi square test, Harvey and Huang (1991) showed that the volatility changes significantly across days of the week for the Swiss franc, the British pound, and the Japanese Yen. However, no strong evidence of the day of the week effect for the Deutsche mark and the Canadian dollar was found. Harvey and Huang (1991) proved that the volatility of the currency futures market is high on Monday, but decrease on Tuesday before reaching its lowest level on Wednesday. Friday volatility change was found to be positive and significantly different from the one on other days of the week[16]. A similar but less dramatic increase in volatility was also observed on Thursday. Harvey and Huang (1991) tried to explain high opening volatility on Thursday and Friday by the public-information announcements, since the most important day for U.S. macroeconomic announcements is Friday[17], and many key announcements take place on Thursday. By showing that US/European FX futures are, on average, twice as volatile during US trading hours as during European trading hours, Harvey and Huang (1991) concluded that US news announcements released during US trading hours are more important than news released during European trading hours. This observation explains the significant impact of the US macroeconomic announcement on the global FX market.

By showing that the Friday effect disappears after the scheduled announcements are controlled for, Ederington and Lee (2001) concluded that high volatility on Friday is explained by the announcement effect. Ederington and Lee (2001) also found an evidence of high Tuesday volatility after incorporating announcement effect variables into the regression equation. However, contrary to Harvey and Huang (1991), Ederington and Lee (2001) suggested that Monday is the lowest volatility day, even after taking into account the impact of the news announcements. They explained low volatility on Monday by relatively small number of the news releases. The evidence of high volatility on Tuesday and low volatility on Monday is consistent with Muller et. al (1990), who reported low Monday volatility for USD/DEM, USD/GBP, and USD/JPY rates and found Tuesday to be the most volatile day for all major exchange rates, apart from USD/DEM[18]. Ederington and Lee (1993) supported Harvey and Huang (1991) hypothesis that public news announcements explain day of the week effect, by showing that volatility differs across days of the week on the announcement days, but not on non-announcement days. Copeland and Wang (1994) provided an

[16] Significant volatility in the FX market on Friday was also documented by Wei and Zee (1998) and Ederington and Lee (2001).
[17] PPI, capacity utilization and unemployment figures are released on Friday
[18] For USD/DEM Tuesday is the second most volatile day after Wednesday.

evidence of the significantly high historical volatility on Thursday, suggesting that Thursday is the most volatile day followed by Monday. Copeland and Wang (1994) explained high Thursday volatility by the release of US weekly money supply figures on Thursday. High Monday volatility, which was also reported by Hsieh (1988) and Baillie and Bollerslev (1989), was explained by the weekend effect. After concluding that Wednesday is the least volatile day in the FX markets, Copeland and Wang (1994) suggested that the markets are relatively quiet before the announcement of important news, with a reduced amount of trading taking place, and therefore lower volatility observed in the markets. The hypothesis that the day of the week effect is explained by the announcement effect has also been documented by Andersen and Bollerslev (1998), Fleming and Remolona (1999) and Ederington and Lee (2001).

Ederington and Lee (1996) suggested that there are intraweek patterns in the Treasury bond and Eurodollar options on futures, driven by significantly low implied volatility on Friday. By hypothesizing that uncertainty, measured by the implied volatility, would be high prior to the release of the scheduled announcements and would fall following the release, Ederington and Lee (1996) explained low implied volatility on Friday by the source of uncertainty being resolved with the release of the scheduled announcements (mainly employment report) in USA. As the evidence, Ederington and Lee (1996) showed that the FX implied volatility tends to fall on Friday with scheduled announcements, but rise on Friday without the announcements. After reporting that the average rise in the implied volatility on Friday without scheduled announcements is somewhat less than the rise on most other days without scheduled announcements, Ederington and Lee (1996) suggested that the traders' trading patterns, and specifically selling pressure on Friday, as documented by Harvey and Whaley (1992), has some, though insignificant effect on implied volatility. Ederington and Lee (2001) confirmed that FX implied volatility increases prior to the release of the scheduled announcements, but suggested that relative to other financial markets, volatility remains high much longer in the FX market before returning to the previous level. By calculating implied volatility using calendar days, Ederington and Lee (1996) reported significantly positive implied volatility on Monday. This finding is consistent with the hypothesis that volatility tends to rise on days without scheduled announcements. Although a fall in the implied volatility on Friday remains statistically significant, Monday effect, which was also reported by Harvey and Whaley (1992) and Fleming et. al (1998), disappears when volatility is recalculated using trading days.

Kim and Kim (2004) found an evidence of significantly low implied volatilities in the early part of the week and significantly high volatility in the later part starting from Wednesday. After stratifying the data set based on the days with and without announcements and observing disappearance of the intraweek patterns in the later part of the week when announcement days only are included in the model, Kim and Kim (2004) suggested that the public announcements are followed by either unchanged or slightly decreased volatility. This phenomenon is consistent with the hypothesis proposed by Ederington and Lee (1996) that the uncertainty is resolved with the release of new information. Kim and Kim (2004) explained low volatility on Monday, the day with few macroeconomic announcements, which is not consistent with the announcement day effect, by the trading patterns in the FX market or the private information. This explanation is consistent with Hsieh and Kleidon (1996) and Anderson and Bollerslev (1998) and supports Han et. al (1999), who suggested that significantly low volatility for the DM and JPY futures in the beginning of the week is due to traders not taking positions in the early part of the week and accumulating private information to get a feel for the market, before actively trading in the later part of the week.

2.3.1.3. Explanations of the Day of the Week Effect in Volatilities

In this section, we discuss theories and hypothesis that explain day of the week effect in the FX implied volatility intraweek patters. These include private and public information hypothesis, contagion effect, liquidity risk theory, and microstructure based explanations.

2.3.1.3.1. Private Information Hypothesis

High Friday volatility reported by Harvey and Huang (1991), Anderson and Bollerslev (1998) and Han et. al (1999) and significant volatility on Monday and on post holiday days reported by Copeland and Wang (1994) is consistent with the private-information (trade timing) models of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990). Private information theory is based on the idea that volatility depends on the trading patterns of the liquidity[19] and informed[20] traders, who prefer to trade when liquidity is highest and the trading costs are lowest. Admati and Pfleiderer (1988) argued that the trading costs would be minimized when informed and liquidity traders trade together, implying that high volume and lower bid-ask spreads come with high volatility, while Foster and Viswanathan (1990) suggested that liquidity traders avoid trading with informed traders when private information is intense and short lived, implying that low volume and wider bid – ask spreads would be associated with high volatility. However, both Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) agreed that the intervals when the transaction costs are minimized, resulting in a jump in the volatility are the open and the close of the market. Within the context of the calendar patterns, as traders start trading on Monday (when liquidity increases and trading costs tend to be low) on the basis of the private information, return and implied volatility anomalies emerge. Unfortunately, it is often difficult to distinguish trading motivated by private information from trading reflecting the market structure and trading process (discussed below).

Admati and Pfleiderer (1988) argued that as European banks close early on Friday about an hour before US markets open, volatility increases significantly due to increased activity of the liquidity traders. Foster and Viswanathan (1990) argued that since traders use private information accumulated during the weekend before the information is publicly disseminated, volatility is significant on Monday. Although,

[19] The term "liquidity traders" refer to the traders who can control the timing of their trades and whose trading is not motivated by the private information.

[20] Informed traders trade based on the private information that comes from advanced knowledge about government actions, observations of order flows, and superior analytical abilities of traders.

using stock market data, Foster and Viswanathan (1993) did not find any evidence of the significant volatility patterns on Monday, the evidence of high Monday volatility accompanied by low volume, supporting the Foster and Viswanathan's (1990) model, has been provided for the international stock markets (Chang et. al, 1997, Berument and Kiymaz, 2003), Treasury bonds (Chang et. al, 1997), commodity futures (Chang et. al, 1997) and the currency futures market (Wei and Zee, 1998). Ignoring a volatility peak observed on Friday reflecting the effects of major market closures, private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) predict monotonically decreasing volatility during the week, assuming that as the week progresses, more and more information is publicly disseminated, resulting in the gradually decreasing volatility.

After confirming that volatility is low on Monday and high on Friday (though reported coefficients were not found to be statistically significant), Wee and Zee (1998) concluded that at least for Friday, the empirical evidence is partially explainable by the Foster and Viswanathan (1990) model, and is inconsistent with the idea that public information is the predominant source of information in the currency market. Wee and Zee (1998) failed to explain the behavior of the market volatility on Monday, but indicated that the lack of the evidence for a high Thursday volatility indicates that public information flow, which tends to increase on Thursday (Harvey and Huang, 1991), is unimportant in explaining volatility patterns in the FX futures.

Harvey and Huang (1991) argued that although it is possible to explain increased stock market volatility during US trading hours by the private information hypothesis, it is more difficult to explain this for the FX market. According to the private information hypothesis, US investor reveal most of the private information when US markets are open, and therefore transaction costs are minimal. However, FX markets are open 24 hours a day and US market is not necessary characterized by the minimal transaction costs, given that the largest FX market is London followed by Tokyo and only then by New York (Krugman and Obstfeld, 1998). Harvey and Huang (1991) suggested that the ability to trade around the clock and high liquidity at non-US markets is the main justification for the argument that public announcements, rather than private information explain market volatility. In addition, higher than average volatility observed on Thursday cannot be explained by, and the U-shaped intraweek pattern is not consistent with the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990).

2.3.1.3.2. Public Information Hypothesis

Anderson and Bollerslev (1998) found Thursday and Friday to be the most volatile days of the week, while Monday was found to be the least volatile. Andersen and Bollerslev (1998) concluded that the clustering of the public information releases on Thursday and Friday explains the day of the week effect. Using the ARCH model, they found significant and positive dummy variables for day of the week effect, but when they included Thursday and Friday news announcements in their model, the dummy variables for Thursday became insignificant, while the coefficient for Friday remained at best borderline significant. Anderson and Bollerslev (1998) concluded that scheduled announcements of the macroeconomic indicators explain the intraday volatility patterns.

Ederington and Lee (2001) studied the determinants of the intraday implied volatility in the interest rate and FX markets by focusing on the past volatilities, the timing of upcoming news releases and the seasonality patterns. Ederington and Lee (2001) concluded that the commonly observed U shaped intraday volatility pattern in the FX market disappears when the announcement effect is controlled for. Contrary to Andersen and Bollerslev (1998), Han et. al (1999), using Hansen (1992) generalized method of moments (GMM), found that even after taking the announcement effect into consideration, the intraday prices of the currency futures for Deutsche mark, Japanese Yen, and to a lesser degree for British Pound still display day of the week pattern[21]. They also concluded that for the currency futures, the day of the week effect is caused by low volatility on Monday and high volatilities

[21] Han et. al (1999) tested the day of the week effect by pooling a trading day into 80 intervals, while Ederington and Lee (1993) tested pooled all intervals together.

on Thursday and Friday. After observing a gradual increase in the volatility during a week, Han et. al (1999) concluded that the day of the week effect in the currency futures is driven not only by the announcements of macroeconomic indicators, but also by other factors, such as private information-based trading or market microstructure. Han et. al (1999) suggested that since the announcements do not alter the day of the week pattern, the currency futures markets process the public information the same way across different days of the week. These findings are contrary to the conclusion reached by Chang et. al (1998) that the US equity markets process the announcements on Monday differently than on other days of the week, but are consistent with Melvin and Yin (2000)[22].

2.3.1.3.3. Contagion Effect

According to Harvey and Huang (1991), the high opening volatilities on Friday can also be explained by the fact that the Friday opening of the US foreign currency futures market coincides with a period of time when major European banks officially close down after a week of trading. According to the so called contagion effect, proposed by King and Wadhwani (1990), the opening or close of the particular market would cause a jump or a fall in the volatility of another parallel market where trading continues. King and Wadhwani (1990) came to this conclusion after observing a volatility jump in the London market when the New York market opened. They also observed a fall in the London exchange volatility in 1968 when the US exchanges were closed on Wednesday. The contagion effect explains not only the link between the volatilities of different geographical markets, but also the link between different asset markets in the same geographic location. Ho and Lee (1998) believed that it is the closure of the stock market that causes volatility to fall, and the closure of the index futures market that causes volatility to rise. In the FX market, Andersen and Bollerslev (1998) found an evidence of the jump in the implied

[22] Melvin and Yin (2000) suggested that the rate of information arrival affects FX volatility, although there is an unexplained part of the volatility patterns, which is probably due to the private information and noise trading.

volatility of USD/DEM and USD/JPY futures, following the opening of trading in a number of Asian financial markets, including the Tokyo interbank market.

Although the contagion model explains the behaviour of some market volatilities, it does not explain the behaviour of other markets' volatilities. Specifically, Werner and Kleidon (1996) found that the opening of the New York stock exchange does not affect the prices and volatilities of the British cross-listed stocks in the London stock exchange. In the FX market, Hsieh and Kleidon (1996) found that the opening of the New York market does not affect quotes in London where trading in foreign exchange still continues. In spite of the reported jump in the FX market volatility, Andersen and Bollerslev (1998) did not find a direct evidence of the increased volatility associated with the termination of the regional trading[23].

2.3.1.3.4. Microstructure Based Explanations

A number of market microstructure[24] based explanations of volatility have been suggested in the recent studies of stock and FX markets. According to the proponents of the market microstructure theories, traders' sudden exposure to the market at the opening and the subsequent need for having a feel for the market before plunging into serious trading could be possible explanations for the calendar patterns. Given that the FX market is a 24 hour market, if the market microstructure does indeed explain the calendar patterns, seasonality in the FX market should be different from the one in the equities. Examples of market microstructure explanations of market volatility include: the effects of trader entry and exit in the FX market (Hau, 1998); trading volume and transactions costs (Hartman, 1999); noise trading (Olivier and Rose, 1999); excessive rational speculation (Carlson and Osler, 2000); order flow shocks (Killeen, Lyons and Moore, 2001); incomplete and heterogeneous information (Evans, 2001); and, FX market transparency (Hau et. al, 2002). Brock & Kleidon, 1992, Romer, 1993, Hsieh & Kleidon, 1996) Han et. al (1999) suggested

[23] Similar results were obtained by Baillie and Bollerlsev (1991), Harvey and Huang (1991) and Dacorogna et. al (1993).
[24] Han et. al (1999) defined the term market microstructure by "the trading practices and trading patterns of market participants that have been developed within the constraints of regulations and rules".

that trading reflecting the market structure and trading process is a more accurate explanation for the intraweek volatility patterns. Brock & Kleidon (1992) and Hsieh & Kleidon (1996) suggested that low volatility on Monday and high volatility on Thursday and Friday is explained by the traders' preference of getting a feel for the market in the early part of the week before actively trading in the second part of the week. According to Han et. al (1999), the trading behavior, trading time horizon, and information processing of the market participants (e.g. hedgers, speculators, day traders, scalpers) has the potential to affect intraweek patterns.

2.3.1.3.5. Liquidity Risk Theory

Another theory that could explain high Monday and Friday volatility is related to the liquidity risk of holding an asset, which is likely to be higher when the markets are closed. Due to the higher liquidity risk after the market close and just before the market opening, the trading and therefore market volatility increases in the opening and close of the trading period. Traders tend to trade heavily during the market close to establish the optimal portfolio position and those wishing to maintain the optimal portfolio position prefer to trade in the beginning of the trading period to adjust the portfolio imbalances that result from the information flow during the period when the markets are closed. This explanation was provided first by Amihud and Mendelson (1987) in their inventory model where they suggested that in a specialist market, a specialist widens the spread in the end of the trading day to respond to the inventory imbalances. Silber (1984), Kuserk and Locke (1993) and Hasbrouck and Sofianos (1993) showed that at the end of the day, volatility increases due to the unwillingness of the traders to keep open positions overnight. If the theory is accurate, high volatility should also be observed at the closing of the trading week on Friday and week opening on Monday.

2.3.1.3.6. Other Explanations

Finally, there are other explanations for the volatility patterns, based on psychological and behavioral factors. Fabozzi et. al (1994) showed that a large price movements are followed by an immediate price reversals, after which the price stabilizes at some level. Phillips-Patrick and Schneeweis (1988) related high Monday dividends to the Monday effect in stocks, while Jaffe and Westerfield (1985) tried to explain a weekend effect by a currency seasonals and clearing procedures. Conally (1988) argued that the cause of anomalies could be the incorrect hypothesis testing procedure, unduly large sample and historical accidents. Finally, Conrad and Kaul (1993) showed that the measurement errors, which could be another explanation for the anomalies, might happen because of the bid-ask errors, non-synchronous trading and price discreteness.

2.3.2. Other Seasonality Patterns in Volatilities

Besides the day of the week effect, other seasonality patterns, such as January effect (Rogalski and Maloney, 1989, Jones and Singh, 1997 and Chen and Zhou, 2001), turn of the month effect (Rogalski and Maloney, 1989 and Barone-Adesi and Cyr, 1994), quarterly patterns (Barone-Adesi and Cyr, 1994), and holiday effect (Copeland and Wang, 1994, Sundkvist and Vikstrom, 2000 and Tanizaki, 2004) have become a topic of several empirical studies. However, the majority studies on the volatility calendar effects, apart from the intraweek patterns, are limited to the stock market. Since there is a limited literature on many volatility calendar effects in the FX market, the focus on the currency market is the main contribution of our study to the existing literature.

Section 2.3.2.1 examines intra monthly patterns, and specifically turn of the year and turn of the month effects. In section 2.3.2.2, we discuss monthly patterns. Section 2.3.2.3 provides an overview of the literature on the holiday effect, while section 2.3.2.4 summarizes other seasonality patters, including quarterly seasonalities.

2.3.2.1. Intra Monthly Patterns in Volatilities: Turn of the Year and Turn of the Month Effects

An existence of the monthly patterns in the asset return series, indicated by the asset returns being significantly higher during the first half of a month and in the last trading day of a month (Ariel, 1987) motivated several studies on the monthly volatility patterns. Martikainen et. al (1995) found a strong evidence of significantly positive implied volatilities in the last five and ten trading days of the month and significantly negative implied volatilities in the first five and ten trading days of the month. The implied volatility during five days preceding and following the turn of the month was found to be positive and statistically significant, indirectly referring to another finding that the turn of the month effect is more evident in the last trading days of the month.

Rogalski and Maloney (1989) examined the behavior of options with January, April, and July expirations around January 1, April 1 and July 1, respectively to determine whether turn of the month effect exists for the stock market implied volatility. They found a statistically significant increase in the volatility in the period prior to mid December, but suggested that volatility tend to decline in the second half of December, with the fall being especially significant in the last and first 2 days of the year. However, Rogalski and Maloney (1989) did not find any evidence of similar volatility patterns in April and July, concluding that in spite of the presence of the turn of the year patterns in the stock market implied volatility, there is no indication of a turn of the month effect.

Building upon the finding that stocks exhibit large returns around the turn-of-the-year (Roll, 1983 and Rogalski and Tinic, 1986) and based on the findings by Smidt and Stewart (1984) that January risk premium for the stock market index is significantly larger than for other months of the year, Rogalski and Maloney (1989) presented evidence that the variance of the returns is significantly higher during January relative to other months of the year. Based on the efficient market hypothesis[25] and in accordance with Pattel and Wolfson (1981), Rogalski and Maloney (1989) examined the possibility that option prices reflect these patterns prior to the year-end, by estimating implied volatility estimates in order to determine if higher return variability at the turn-of-the-year is anticipated and reflected in call option prices. Rogalski and Maloney (1989) found that during the last six weeks of the calendar year, implied volatility estimates trend upward, but tend to decline in the period from ten days preceding the year-end to ten days after the year-end. In addition, the increase in implied volatility prior to the turn of the year was found to be stronger for options that expire in January than for options that expire in later months. Rogalski and Maloney (1989) concluded that the results could be explained by the argument that in the period from mid November to mid December, the market participants anticipate the market to be volatile prior to the turn of the year, and believe that the high volatility period begins about ten days prior to the year-end.

[25] The efficient market hypothesis predicts that the trends and patterns, such as turn of the year effect would be known and anticipated by the financial markets.

This explanation was later named as the seasonal risk premium hypothesis (Jones and Singh, 1997) and is consistent with the efficient market hypothesis. By examining the behavior of options with April expirations around April 1 and the behavior of options with July expirations around July 1, Rogalski and Maloney (1989) concluded the results are indicative of the presence of a turn of the year, rather than turn of the month effect.

Barone – Adesi and Cyr (1994) hypothesized that if the turn of the year effect exists, indicated by a January being associated with a higher expected volatility than other months, the effect would be a gradual increase in the level of the implied estimates throughout December, followed by a decrease throughout the month of January. The presence of insignificant turn of the year effect was provided for only 2 out of 7 years studied by Barone – Adesi and Cyr (1994). After carrying out the analysis using an alternative turn of the year variable, which is coded to capture the proportion of time to maturity represented by the last trading day of the year and the first four trading days of the consecutive year, Barone – Adesi and Cyr (1994) concluded that a January seasonality in the implied volatility is not significant.

The inconsistency between the results obtained by Rogalski and Maloney (1989) and Barone – Adesi and Cyr (1994) could be explained by several factors. The most obvious one is that Rogalski and Maloney (1989) studied turn of the year effect for the implied volatilities of 29 individual stocks by estimating OLS regression estimates, while Barone – Adesi and Cyr (1994) carried out similar study for the implied volatility of S&P 500 futures. Besides, Rogalski and Maloney (1989) covers the sample period of 1973 to 1984, while Barone – Adesi and Cyr (1994) focused on a more recent period of 1984 to 1990. Therefore, differences in the results could be explained by a diminishing January effect, supported by Maberly and Maris (1991), who noted that while January effect has not altogether been eliminated, arbitrage opportunities in the S&P 500 have been substantially reduced since the advent of derivative security markets in 1982 and 1983. While Rogalski and Maloney (1989) used daily closing prices to estimate implied volatilities, Barone –

Adesi and Cyr (1994) used weekly closing data, motivating this by the fact that the use of daily time series would result in numerous missing observations. However, the use of so low frequency data affects the accuracy of the analysis carried out by Barone – Adesi and Cyr (1994) and could explain different results reported by the papers.

Jones and Singh (1997) confirmed the existence of the turn of the year effect in the equity market, but argued that the explanations provided by Rogalski and Maloney (1989) might be inaccurate. According to Jones and Singh (1997), an alternative explanation for the turn of the year effect is the portfolio-rebalancing hypothesis, documented by Ritter and Chopra (1989). The hypothesis is based on the tax-loss selling by individuals or portfolio window dressing by institutions theories (Reinganum, 1983 and Haugen and Lakonishok, 1988), which predict a selling pressure in bad performing stocks prior to the turn of the year and buying pressure in risky stocks, following the turn of the year. Jones and Singh (1997) suggested that as the result of the price pressure in stocks, observable asset prices would be depressed below the stock prices implicit in option prices, resulting in the volatility estimates implied from call options being biased upward and those implied from put options being biased downward, regardless of whether actual volatility increases or not. According to Jones and Singh (1997), as the year-end approaches, the seasonal risk premium hypothesis of Rogalski and Maloney (1989) would predict an increase in the volatilities implied from both call and put options, while the portfolio-rebalancing hypothesis of Ritter and Chopra (1989) would predict an increase in the call option volatilities and decrease in the volatilities of the put options. According to both theories, these trends should recede after the year-end.

A third theory that could explain the turn of the year effect is the concentrated liquidity-trading hypothesis by Lakonishok and Smidt (1986). According to the concentrated liquidity-trading hypothesis, the trading volume is abnormally high at the turn of the year due to window dressing and the reduction or postponement of taxes. According to the private information hypothesis of Admati and Pfeiderer

(1988), increased trading volume caused by the concentrated liquidity trading would attract informed traders, making prices more informative and more volatile. Lakonishok and Smidt (1986) predicted that volatility should increase at the turn of the year, because of the private information based trading. Jones and Singh (1997) found that volatilities implied from call options tend to increase prior to the year-end, but did not detect significant changes in the level of the volatilities implied from put options. Jones and Singh (1997) concluded that the turn of the year effect is explained by both portfolio-rebalancing and the concentrated liquidity-trading hypothesis, by suggesting that the decrease in the put option volatilities attributable to the portfolio-rebalancing hypothesis is offset by the increase in the volatility implied from the concentrated liquidity trading theory.

2.3.2.2. Monthly Patterns in Volatilities

Ferris et. al (2003) examined volatility embedded in the September corn futures option markets for the sample period 1991-2000[26] and found an increasing trend in the implied volatility over January to July period. However, they concluded that the seasonality effect does not exist, since it is difficult to find any other genuine annual seasonal pattern that fits all the years. Ferris. et. al (2003) listed the technological changes, the impact of commodity funds, international trade, weather, price stagnation and the pace of planting as factors that impact the market price and volatility. After investigating average equity volatility month by month, Chen and Zhou (2001) suggested that volatility is relatively low and stable from February to July, but tends to be higher and more volatile in the period starting from August and ending in November. Chen and Zhou (2001) discovered October to be the most volatile month, followed by November and then January. After ignoring October 1987 crash, they found November volatility to be the highest, followed by October and January average volatilities. Chen and Zhou (2001) tried to explain high November volatility by the early portfolio rebalancing strategy of institutional investors in November and by the tax selling, as suggested by Bhabra et. al (1999).

[26] They focused on the corn futures contracts since they are the most actively traded agricultural futures contract on the CBOT.

Chen and Zhou (2001) also reported an interesting result that the average monthly volatility in January is one of the lowest during the first sample period, but becomes the highest during the second sample period. They also found an evidence of strong positive autocorrelation in the volatility, implying that if the market volatility is high for one month, usually it tends to be high for the next month.

2.3.2.3. Holiday Effect in Volatilities

As suggested by French (1980) and French and Roll (1986) for the equity markets and Fleming et. al (1998) for the FX market, options seem to be priced under the trading day hypothesis. If the trading day hypothesis is valid, holidays would cause no extra volatility. However, as suggested by Sundkvist and Vikstrom (2000), holidays do cause an unobserved volatility. Copeland and Wang (1994) studied seasonality patterns in the FX market, by including two dummy variables into the model, one denoting a day immediately preceding a holiday and the other denoting a day immediately after. They suggested that the markets are usually more active when a holiday longer than a normal weekend is approaching with a greater variance caused by an increased amount of trading. Although, Copeland and Wang (1994) reported Monday to be on average the second most volatile day of the week, volatility on days immediately following holidays was found to be insignificant. Copeland and Wang (1994) explained this phenomenon by the fact that it takes time for the markets to warm up after longer periods of inactivity, offsetting to some degree the variance which otherwise would increase due to the longer time that has elapsed.

Andersen and Bollerslev (1998) observed that Christmas Day and New Year Day both have close to zero quote activity, and therefore low volatility. Similar, though not to such extent, low activity has been observed on other US holidays representing Thanksgiving, President's Day, Easter, Memorial Day, July 4, and Labour Day. Some regional, non-US holidays were found to be associated with subdued, rather than extremely low volatility. Such extreme slowdown in market activity over some holidays resembles the behavior of the volatility on weekends.

Tanizaki (2004) found an evidence of the holiday effect for the Japanese stock index, by concluding that the number of non-trading days, including weekends, do affect market volatility. Building upon an idea that there is a positive correlation between return volatility and trading volume (Nelson, 1991 and Watanabe, 2000) and that the volatility depends on the amount of the information, which is roughly equivalent to the number of non-trading days, Tanizaki (2004) concluded that the longer the non-trading period between two trading days, the higher volatility is. However, Tanizaki (2004) included weekends in his analysis, and as the result, most of the holiday effects appear on Monday (922 out of 1101), which are followed by two non-trading days. Therefore, Tanizaki's (2004) study is inconclusive, since the results could be caused by the weekend effect associated with high Monday volatility, rather than the holiday effect.

2.3.2.4. Other Seasonality Patterns in Volatilities

Penman (1987) provided an evidence of a quarterly effect in the stock returns, indicated by returns being significantly higher early in calendar quarters two through four. Barone – Adesi and Cyr (1994) tried to confirm whether quarterly effect, documented for the return series by Penman (1987), exists in the implied volatilities of the S&P 500 futures options. Contrary to the seasonality observed in the stock return series, no significant results were reported.

In addition to the fixed calendar effects, such as a day of the week effect, January and holiday effects, some papers focused on the impact of moving calendar events on the asset return and volatility series. Major moving calendar events, such as Ramadan could potential have significant effects on economic and financial variables. The impact of Ramadan on the equity market volatility has been demonstrated for the Pakistani stock market by Husain (1998) and for the Saudi Arabian stock market by Seyyed et. al (2005). Seyyed et. al (2005) explained a drop in the volatility during the month of Ramadan by the reduced trading activity or change in investor behavior stemming from a variety of factors, such as reduced banking hours, Islam's prohibition against speculation and use of interest which would affect margin trading, and greater religious orientation of the market participants leading to lower interest in trading, among others.

2.3.3. Summary

Existing literature on the day of the week effect in the equity implied volatilities found evidence of high implied volatility in the beginning of the week that tends to fall as a week progresses. In contrast, the FX volatility was found to be low on Monday and high on Thursday and Friday. Among numerous explanations for the day of the week effect documented in the academic literature, private and public information hypothesis are more common. Several papers have been published on the holiday, turn of the year and turn of the month effects in the equity implied volatilities. There is also an evidence of significantly different equity and commodity implied volatilities in January, September, November and December.

Although there is some, though limited, literature on the day of the week effect in the FX implied volatilities, the existing literature on other seasonality patterns is limited to the equity markets. Besides, the academic papers on the intraweek seasonality patterns in the currency implied volatilities (Ederington and Lee, 1996 and Kim and Kim, 2004) tend to focus on the FX futures, as opposed to FX cash markets. The coverage of the FX cash market and the study of various seasonality patterns, such as turn of the year, month of the year and holiday effects fills a gap in the existing literature on the FX calendar effects. Besides, the use of a sample period from January 1994 to December 2003 provides an opportunity to cover pre and post euro periods with the aim of identifying the impact of euro on the currency implied volatility patterns.

2.4. RELATION BETWEEN RETURNS AND VOLATILITIES

In spite of the recently increased popularity of the empirical studies on the implied volatility patterns, the literature on the relation between financial asset returns and volatility is limited[27]. The existing studies documented an evidence of a significant relation between implied volatility and contemporaneous returns in the equities and FX futures[28]. Besides, the relation is stronger for negative rather than positive returns, at least in the equity markets. The existing literature also suggest that there is a strong relation between implied volatilities and forward FX futures returns, with the relation being more significant in the case of the negative and extremely large returns.

We contribute to the existing literature, by studying the relation between implied volatility and both contemporaneous and forward-looking returns in the cash FX market and by addressing the asymmetric feature of this relation in terms of the direction of the exchange rate movements, as well as its size. Building upon the recognition that the announcement effect tends to explain the implied volatility patterns (Ederington and Lee, 1996), we also study the relation between FX returns and implied volatilities, by differentiating between the announcement and non-announcement days. Finally, our another major contribution to the existing literature is that we break the sample period of 1994-2003 into two sub samples of 1994-1998 and 1999-2003, to study the impact of euro on the volatility – return relation.

In Section 2.4.1, we discuss relation between contemporaneous returns and implied volatilities, while in section 2.4.2, we focus on the asymmetric feature of this relation. Section 2.4.3 examines the relation between forward looking returns and implied volatilities, while section 2.4.4 concludes.

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[27] This could be explained by the belief that the financial markets are efficient, and therefore volatility cannot provide relevant information about contemporaneous and future asset prices (Giot, 2003)
[28] According to the volatility feedback effect, increase in the volatility leads to negative asset returns, while the leverage effect assumes that a fall in asset prices cause an increase in the market volatility.

2.4.1. Relation Between Contemporaneous Returns and Implied Volatilities

The existing literature on the relation between financial market volatility and contemporaneous asset returns is mainly limited to the equity markets. We are only aware of one paper (Kim and Kim, 2004) that studied the relation between contemporaneous returns and implied volatilities in the FX market. We discuss the findings of the papers on both equity (Section 2.4.1.1) and FX (section 2.4.1.2) markets and provide explanations in section 2.4.1.3.

2.4.1.1. Non FX Markets

A significant negative correlation between stock returns and market conditional volatility has been documented by Black (1976), French et. al (1987), Nelson (1991), and Glosten et. al (1993). Schwert et al., (1987) found unexpected increases in volatility to be associated with negative stock returns, and Lundblad (2007) concluded that the relation between stock market conditional volatility and returns is positive. Harrison and Zhang (1998) found an evidence of a significantly positive risk and return relation at long holding intervals, such as one and two years, but no evidence of such relation at short holding periods such as one month. In contrast to most studies, Baillie and DeGennaro (1990), Theodossiou and Lee (1995) and Koulakiotis (2006) did not find any evidence of the significant relation between market volatility and asset returns.

Fleming et. al (1995) documented a significant relation between CBOE Market Volatility Index (VIX), a volatility index for S&P 100 index, and the changes in the equity index. Consistent with Schwert (1989), Fleming et. al (1995) also demonstrated that negative stock market movements result in the increased market volatility, while positive returns are associated with reduced volatility (see also Davidson et. al, 2001). Simon (1997) obtained similar results for Treasury Bond futures options, while Giot (2003) also found a strong negative relation between contemporaneous changes in the implied volatility indices and underlying stock indices for both S&P 100 and NASDAQ. Litvinova (2002) and Bollerslev et. al

(2006) found evidence of a statistically significant negative relation between stock market returns and volatility.

2.4.1.2. FX Markets

Kim and Kim (2004) found evidence of a significantly positive relation between implied volatility and returns for the Yen and the Swiss franc futures and of a significantly negative relation for Sterling and Canadian Dollar futures. Consistent with the earlier findings of Fung and Hsieh (1991), no evidence of a significant volatility return relation was found for Deutschmark futures. In addition, Kim and Kim (2004) concluded that higher currency future volatility is associated with the large currency market fluctuations, regardless of the direction, meaning that both appreciation and depreciation of US dollar against other currencies cause significant changes in the implied volatility.

2. 4.1.3. Explanation for Contemporaneous Returns and Volatilities Relation

There are two main theories, which explain a relation between market volatility and contemporaneous asset returns: volatility feedback effect and leverage effect. Schwert et. al (1987) originally proposed time-varying-risk-premium hypothesis, which later developed into the volatility feedback effect (Hentschel, 1992). They observed that volatility is typically higher after the stock market falls than after it rises, which explains the negative correlation between stock returns and future volatility. Volatility feedback effect notion suggests that, "if volatility is priced, an anticipated increase in volatility raises the required return on equity, leading to an immediate stock price decline" (Wu, 2001). Volatility feedback could explain return – volatility relation for other asset classes, including FX.

The second theory explaining return - volatility relation is the leverage-effect theory and was initially proposed by Black (1976) and Christie (1982), who tried to explain the asymmetric equity market volatility-return relation by the changes in the financial leverage (the debt-equity ratio). Unlike volatility feedback effect, which states that volatility changes cause significant fluctuations in the asset prices, leverage effect theory is based on the notion that a fall in the asset prices would increase financial leverage, and cause expected volatility to rise. However, Figlewski and Wang (2001) stated that the magnitude of the price changes on the market volatility is too large to be fully explained by the financial leverage documented by Black (1976) and Christie (1982). In addition, Simon (1997) found an evidence of volatility – return relation that exists on the stock market for the Treasury bond market, where there is no leverage effect. Given that there is no leverage effect in the FX market, so the evidence of the relation in the FX market could contradict the leverage effect theory of Black (1976) and Christie (1982).

Bekaert and Wu (2000) studied the relation between stock returns and volatilities using various portfolios constructed from Nikkei 225 stocks to examine leverage and volatility feedback effects. They rejected the pure leverage model of Christie (1982) and attributed most of the volatility-return correlation to the volatility feedback effect, noting that the relation becomes significant following negative market news. However, according to Poterba and Summers (1986), the relation between equity returns and implied volatility cannot be attributed to volatility feedback, since changes in volatility are too short in time to have a major effect on stock prices. Bollerslev et. al (2006) concluded that volatility-return relation is explained more by the leverage rather than the volatility feedback effect, but suggested that the observed slowly decreasing correlation between the volatility proxy and past returns is too significant to be solely explained by the leverage effect. Campbell and Hentschel (1992) came to the conclusion that the relation between equity returns and volatility is explained by both theories: leverage effect and volatility feedback effect. Nevertheless, they stated that even several theories taken together cannot fully explain the relation between market returns and volatility.

2.4.2 Asymmetric Relation Between Contemporaneous Returns and Volatilities

It has long been recognized that volatility tends to react more to negative than to positive returns. The majority of the papers cover equity and bond markets (discussed in Section 2.4.2.1), with only two papers focusing on the FX market (Davidson et. al., 2001 and Kim and Kim, 2004, discussed in Section 2.4.2.2). Section 2.4.2.3 provides explanations for the asymmetric feature of the relation between contemporaneous returns and implied volatility.

2.4.2.1. Non FX Markets

Schwert (1989, 1990) concluded that the relation between contemporaneous returns and implied volatility is asymmetric, after observing that the expected equity market volatility is more sensitive to negative than to positive equity return. Fleming et. al (1995) found that both daily and weekly changes in VIX are more sensitive to the negative than positive stock market moves. Dumas et. al (1998) confirmed these findings, but used implied volatility of S&P index, rather than VIX itself. Similarly, Nelson (1991), Glosten et. al (1993), and Engle and Ng (1993) have documented a significant increase in the financial asset volatility following negative, but not positive news.

In contrast, Ghysels et. al (2004) concluded that the relation between market return and volatility remains unchanged when the volatility is allowed to react asymmetrically to positive and negative returns. Malz (2000) studied the asymmetry in asset return – implied volatility relation for the S&P equity index, interest rates futures and spot exchange rates, and found that the asymmetry in the causality test results coincide with the mean returns. For example, S&P 500 implied volatilities were found to predict positive S&P 500 returns better than they do negative returns, simply because of a larger number of positive return series in the sample.

Davidson et. al (2001) extended the work of Fleming et. al (1995) to a broad variety of asset categories, including agriculture, interest rate, livestock, metals, energy, currencies, and the S&P 500 Index futures. Davidson et. al (2001) concluded that while some markets, e.g. livestock and petroleum, do behave like stock and bond markets, most do not. In many of the agricultural and precious metal markets, for example, the relations between the asset returns and implied volatilities is exactly opposite to what is observed in equities: implied volatility increases following positive returns and declines following negative returns. Davidson et. al (2001) explained an increase in the implied volatility on agricultural futures by the expected weather related shortages in the commodities that cause immediate price increase and impose considerable uncertainty on the behavior of the commodities' prices in the future. Therefore, a decrease in the implied volatility would be explained by the excess supply for the commodities, resulting in the immediate price drop and reduced uncertainty about future supply and future commodities' prices. Davidson et. al (2001) concluded that the relation between implied volatility and the underlying asset returns varies greatly across different categories of underlying assets, but to a lesser extent across specific markets within specific asset category. This means that the relation between volatility and returns of the major exchange rates is likely to be similar.

2.4.2.2. FX Markets

In the FX market there is little evidence of the asymmetric reaction in implied volatility to positive compared to negative returns. Kim and Kim (2004) found little evidence of asymmetric response of implied volatility in the FX market (confirming Davidson et. al, 2001). They found that only options on the Canadian Dollar futures show the similar response pattern to those observed in equity and bond markets. For the other currency future options examined, both USD appreciations and depreciations were found to cause a statistically significant impact on the implied volatility. Kim and Kim (2004) concluded that in DM, the impact of positive and negative futures movements is statistically the same, while the impact of positive JPY and CHF returns and the negative GBP returns is statistically larger.

4.2.3. Explanation for Asymmetric Relation Between Returns and Volatilities

The findings that negative returns tend to have more significant impact on the market volatility, compared to positive returns could also be explained by the existing theory that volatility is typically higher after the release of the bad news than it is after the announcement of the good news. Some researchers empirically supported the asymmetric impact of volatility feedback, known as a sign effect (see Laakkonen, 2004) others have contended that such volatility feedbacks are significant but too small to account fully for the observed asymmetric patterns in asset prices (see Poterba and Summers, 1986).

After studying a relation between contemporaneous returns on stock indices and subsequent implied volatility indices, Giot (2003) found evidence of the asymmetric relation for the S&P 100 index (negative returns yield much larger relative changes in the VIX index than positive returns) and concluded that the impact of S&P 100 returns on the implied volatility index is sharper in low volatility periods, but is somewhat muted in the high-volatility period. He tried to explain this phenomenon by option traders reacting aggressively to negative returns in low volatility periods by strongly bidding up implied volatility, but being reluctant to do so in high volatility trading environments.

2.4.3. Relation Between Forward Looking Returns and Volatilities

Although, most of the academic papers on the relation between returns and implied volatilities focus on the contemporaneous returns, some cover forward-looking returns. Section 2.4.3.1 examines the papers on the equity forward-looking returns, while section 2.4.3.2 provides an overview of the papers focusing on the FX market.

2.4.3.1. Non FX Markets

Glosten et. al (1993), Lundblad (2004), and Bollerslev et. al (2006) focused on the relation between forward looking asset returns and implied volatilities and did not find any significant impact of the volatilities on the expected returns. Ghysels et al., (2005) used longer time series and higher frequency intraday data and found that there is a statistically significant relation between expected returns and volatility, while Boyle et. al (1999) concluded that the option market anticipates the direction of the spot market moves. Some practitioners suggest that very large implied volatility levels do indeed indicate oversold markets, so there should be positive relation between implied volatility and future returns. Giot (2003) provided some evidence that positive (negative) forward-looking equity returns are driven by extremely high (low) levels of the implied volatility indices. However, as indicated by Giot (2003), one must wait for extremely high levels of implied volatility to get attractive positive forward-looking returns.

2.4.3.2. FX Markets

Lyons (1988) suggested that currency implied volatilities can predict currency excess returns. Malz (2000) assessed the ability of the implied volatility to provide early warning of market stress for various assets, including futures on the equity indices, interest rates, bonds, commodities and the FX rates. For the FX market Malz (2001) found a strong relation between implied volatilities and future returns for

USD/EUR and USD/JPY FX rates, with the relation being more significant in the case of the negative returns.

After obtaining the kurtosis and skewness for the all assets in the study, Malz (2000) also inferred that the results appear to be related to the assets' skewness and kurtosis. The predictive accuracy of the implied volatility signal is the highest for the S&P index and dollar-Thai baht exchange rate, assets with particular high kurtosis and absolute value of skewness. For DEM/USD, with virtually no skewness and kurtosis, the predictive accuracy of the signal was found to be low. Bates (1991) also reported similar findings, concluding that the skew may be a more sensitive predictor of market stress than the level of implied volatility.

2.4.4. Summary

There is an evidence of a significant relation between implied volatility and contemporaneous returns in the equity and FX markets. According to the volatility feedback effect, increase in the volatility leads to negative asset returns, while the leverage effect assumes that a fall in asset prices cause an increase in the market volatility. Besides, the relation is stronger for negative rather than positive returns, at least in the equity markets. The existing literature also suggest that there is a strong relation between implied volatilities and forward FX futures returns, with the relation being more significant in the case of the negative and extremely large returns.

Most of the papers on the relation between implied volatility and contemporaneous returns focus on the equity market and currency futures. Besides, the existing empirical studies on the asymmetric feature of this relation are limited to the impact of positive vs. negative returns on the implied volatility of the stock indices and currency futures. This study contributes to the existing literature, by studying the relation between implied volatility and both contemporaneous and forward-looking returns in the cash FX market and by addressing the asymmetric feature of this relation in terms of the direction of the exchange rate movements, as well as its size. Building upon the recognition that the announcement effect tends to explain the implied volatility patterns (Ederington and Lee, 1996), we also study the relation between FX returns and implied volatilities, by differentiating between the announcement and non-announcement days. Finally, our another major contribution to the existing literature is that we break the sample period of 1994-2003 into two sub samples of 1994-1998 and 1999-2003, to study the impact of euro on the volatility – return relation.

2.5. IMPACT OF EURO

In this section, we discuss the existing literature on the impact euro had or is expected to have on the FX market.

A limited number of papers have conducted a study on the impact of Euro adoption as a single currency on January 1st, 1999, on the FX volatility. Some predicted increase in the volatility (Masson and Turtelboom, 1997, Benassy-Quere et. al, 1997, Obstfeld, 1998 and Eichengreen, 2000) due to ECB's focus on price stability and exclusion of lender of last resort responsibilities. In contrast, Mundell (1998) and Corsetti and Pesenti (1999) predicted decreased volatility because of the ECB's mandate for price stability, while Mussa (2000) suggested that volatility should remain unchanged, because of the no change in Eurozone's major trading relationships brought about by the single currency's introduction. Mussa's (2000) expectations of future trading relationships among countries deviate from those of Cohen (1997), Frankel and Rose (1997) and Benassy-Quere et. al (1997) who believed that Eurozone would become more of a closed economy, increasing exchange rate volatility, because ECB would be less concerned with external stability. Although Masson and Turtelboom (1997) came to the conclusion that Euro adoption would lead to increased uncertainty, they mentioned that the ECB's use of monetary targeting as opposed to inflation targeting, credibility of national commitments to EMU and public confidence in the EMU's institutions for maintaining a stable exchange rate inhibits euro stability.

Using actual quarterly data, Coppel et. al (2000) reported no significant change in the volatility after January 1, 1999. The use of quarterly data is likely to result in the biased estimates as there are only four quarterly observations in the post euro period data set[29]. Hau et. al (2002) used monthly data in their studies and found an evidence of the decreased, albeit not statistically significant, volatility in EUR/DEM – USD rate, and statistically significant increase in the EUR(DM)/JPY

[29] the study was conducted in 2000, so covered only one year after the introduction of euro

volatility. The problem with this study was that Hau et. al (2002) used monthly data that resulted in less than fifty observations, which is insufficient to formulate a conclusion about the behavior of volatility in post January 1999 period. On the other hand, Honohan (2002) and Franks (2002) did not find a statistically significant increase in the exchange rate spread after the introduction of euro and therefore questioned the findings of Hau et. al (2002). Using daily FX return series, Heaney and Swieringa (2003) concluded that the currency volatility tends to increase after the introduction of Euro. Heaney and Swieringa (2003) explained this behavior by the adoption of Euro as an international vehicle currency, which as Portes and Rey (1998) argue, was one of the main objectives of EMU and planned expansion of the European Union. Although the stability of the exchange rate was one of the major intentions of euro introduction, which was not achieved due to the increased exchange rate volatility, as pointed out by Eichnegreen (2000), the efficiency gains were attained.

2.6. SUMMARY

In this chapter, we examined the existing findings on the seasonality patterns in the financial market returns and volatilities, highlighting our key contributions to the existing literature. In order to identify the major gaps in the existing literature, which we intend to fill, we tried to answer three main questions:

- *Is there any evidence of the seasonality patterns that we intend to test?*
- *Which financial markets do existing studies focus on?*
- *What type of data has been used in the existing literature?*

We found that the existing literature has indeed documented the existence of some form of anomaly or relation in the financial market returns and volatilities. However, based on the existing literature, it appears that most of these patterns are not stable over time- they appear in some periods, disappear in certain periods and reappear in others. Given that only few of the studies extend beyond January 1999 (when Euro was officially adopted as a single European currency), our study contributes to the existing literature by covering pre and post euro periods, enabling us to understand the impact of euro and identify the patterns that emerged or faded over time.

We also found that the existing literature on many anomalies and seasonalities is limited to the equity markets. For some patterns, the existing literature on the FX market is virtually non-existent, while for others the focus is on the FX futures, as opposed to FX cash markets. The coverage of the FX cash market would help to fill a gap in the existing literature on the FX calendar effects and resolve the problem of thin trading, also known as the non-synchronous trading problem (via the focus on the cash rather than futures market).

Finally, it appears that most of the existing studies use a limited number of the variables (eg announcements) to explain prices changes and volatility in a limited number of the exchange rates over a limited period of time. We contribute to the existing literature by using more extensive data (eg sixteen macro announcements, including the surprise element of those news releases, as well as interest rate and central bank intervention announcements, both US and non US holidays) to explain price changes and volatility in all four major FX rates using a ten year period enabling us to compare FX volatility behavior prior to and after the introduction of euro. The data used in our study is examined in detail in the following chapter.

CHAPTER 3. DATA

Chapter 3 examines the data used in our study. The daily data on the major FX rates (USD/EUR[1], USD/GBP, USD/CHF and USD/JPY) is from DataStream and Olsen and Associates. EUR is taken to be the linear successor to the DEM on the grounds that, in the pre-euro period, the DEM was a pan-European vehicle currency (Hartmann, 1998). The quotes were obtained at the close of each day (based on GMT) for the ten-year period from January 1994 to December 2003. FX daily rates have been extracted from the Datastream database, while implied volatilities data have been obtained from Olsen and Associates. Implied volatility quotations were extracted by applying the Dacorogna et al. (1993) filter to the data to identify probable errors.

The chapter is organized around three sections. Section 3.1 focuses on the FX return series, while section 3.2 is dedicated to the implied volatilities data. Section 3.3 provides a summary of the data on the macroeconomic news announcements and holidays. Finally, section 3.4 provides a brief summary of the chapter.

[1] USD/DM used as a proxy for USD/EUR in Jan 1994 – Dec 1998 period

3.1. FX Return Series

The data frequency of the FX prices is daily. Since asset prices adjust very rapidly to new information and shocks, a lower observation frequency, such as weekly, would likely be longer than the adjustment period. Glosten et. al (2004) found an evidence of insignificant volatility – return relation after using monthly data, but concluded that the risk-return trade-off becomes statistically significant when daily data is used. Since asset prices exhibit random fluctuations due to noise and liquidity, high frequencies, such as intraday data, may obscure their responsiveness to changing market conditions.

In order to avoid the problem with OLS residual assumptions (normality, homoscedasticity and independence of the regression coefficients), similar to Fleming et. al (1995) and Kim and Kim (2004), the daily changes in the exchange rates, rather than the exchange rate series, are used to detect return anomalies. The use of the daily changes is also justified by the fact that the FX time series may not be stationary. Continuously compounded, rather than discrete returns are used, given that the use of lognormal changes[2] in the asset prices help to bring the asset prices and residuals to normality and reduce autocorrelation[3] among residuals. Continuously compounded or lognormal returns have been calculated as following:

$$R_{xtc} = \ln(1+R_{xt}) = \ln(P_{xt}/P_{xt-1}) \qquad (3\text{-}1)$$

where,

R_{xtc} – the compounded return on the exchange rate in period t

R_{xt} – the discrete return on the exchange rate in period t

P_{xt} – the exchange rate[4] in period (day) t

P_{xt-1} - the exchange rate in period (day) t-1

[2] The use of the log transformation is preferable when the skewness of the error variables and the relation between error variance and the volatility are positive. Another advantage of using log transformation, relative to using absolute values of the variable or other forms of the transformation, such as squared values, is that the log transformation effectively eliminates the extreme outliers, resulting in more robust regression coefficients (Andersen and Bollerslev, 1998).

[3] We also include lagged values of the FX price and implied volatility changes in the regression model to account for a possible autocorrelation among residual coefficients.

[4] Expressed as USD per one unit of foreign currency

In section 3.1.1, we discuss the descriptive statistics for the FX return series used in our study.

3.1.1. Descriptive Statistics for FX Return Series

Table 1 provides the descriptive statistics of data for four major exchange rates (the holidays are omitted, while no extreme observations are omitted from the data set to be consistent with the existing literature). Figure 1 shows that the exchange rates of USD/GBP (0.74%) and USD/CHF (0.71%) display the highest[5] average daily rate of return. The smallest average daily rate of return is observed for USD/JPY, and is equal to 0.16%. From Table 1, it is possible to make comments about historic volatilities of the exchange rates. Although USD/JPY has the lowest average daily return, it has the highest standard deviation of 0.7437 and the largest extreme absolute values. USD/CHF is also relatively volatile currency pair, since its standard deviation (0.6964) for the ten-year period of 1994-2004 is not very different from the standard deviation of USD/JPY.

Only for USD/GBP, the skewness value (-0.0522) is within a normality range at 95% confidence level, implying that non-normality of data distribution for USD/GBP can be rejected at 95% confidence level. For the remaining exchange rates, skewness is significantly different from zero at 95% confidence level, suggesting that the data are skewed right, and that the right tail is heavier than the left tail. For all the exchange rates, the kurtosis values are significantly different from three and excess kurtosis reported in Table 1 is significantly different from zero at 95% confidence level. The excess kurtosis values are positive, implying that data set have a distinct peak near mean, decline rather rapidly and have heavy tails (the normality tests also confirm the conclusion implied by skewness and kurtosis[6]). Kurtosis values are significantly different from zero, which leads to the conclusion

[5] Though not statistically significant

[6] The results of the Anderson-Darling test are large enough to reject the normality at 99% confidence level. For Ryan-Joiner tests, the R-values are under unity and the normality is rejected at the 99% confidence level. For Kolmogorov-Smirnov test, the D values obtained for four exchange rates are well below 0.16, indicating that normality is rejected at 99% confidence level. The Chi square test of normality also suggests that the distribution of return series for all major exchange rates is not normal.

that the return series are heteroscedastic, meaning that the data sets do not have uniform variance (confirming Engle and Bollerslev, 1986 and Andersen and Bollerslev, 1994).

The autocorrelation functions for the FX rates at 75 lags suggest that the return series are not autocorrelated even at the first lags[7]. The absence of autocorrelation leads to the conclusion that the FX market is efficient in a weak form, and the prices do not depend on the lagged values (confirming Wasserfallen and Zimmermann, 1985). Almost zero autocorrelation is explained by the use of low frequency (daily) data[8]. The correlation coefficients for all FX rates (see Table 2) are positive and significantly different from zero. The exchange rates of USD/EUR and USD/CHF show the highest degree of correlation (0.728), which could be explained by the geographic proximity of the regions, and the fact that the currencies' dynamics is driven by the same economic fundamentals. The second highest correlation is observed between USD/CHF and USD/GBP (0.574), which is also explained by the geographic and economic factors. The correlation is not significant between the exchange rates of US Dollar to the European currencies and USD/JPY. This phenomenon is explained by the lack of interdependencies between the European and Japanese economies. Another explanation for low correlation is the difference in time zones, since neither European nor American markets are open, when markets are active in Japan and other Asian markets. Castren and Mazzotta (2005) also provided an evidence of high degree of correlation between the major bilateral exchange rates, also mentioning that the positive correlation is higher in the post-euro sub-sample.

Table 3 presents the descriptive statistics for the major exchange rates in two 5-year sub periods of 1994-1998 and 1999-2003. As per Figure 2, all exchange rates, but USD/GBP, display lower average daily rate of return in 1994-1998 than in 1999-2003. The exchange rate of USD/GBP is the exception, with the record high rate of return (0.91%) in 1994-1998 and relatively low return of 0.56% in 1999 – 2003. The

[7] available upon request

[8] Goodhart and Figliuoli (1991) also found that the negative first order autocorrelations diminish as the frequency of data decreases

exchange rate of USD/JPY is the only exchange rate that has the negative rate of return (negative 0.0013%) in 1994-1998, which becomes positive 0.44% in the next five-year period of 1999-2003. As the result, the exchange rate of USD/JPY is the only currency pair, for which the difference between the medians of the return series in two sub-periods is significant[9] at 5% significance level. The exchange rate of USD/CHF is the most stable currency pair, since its mean return increases only by 25% in the period of 1999-2003 compared to 1994-1998.

The historical volatility of the exchange rates indicated by the standard deviation of return series is similar in both sub-periods. For the exchange rates of USD/EUR and USD/CHF, standard deviation of returns is higher in 1999-2003 than in 1994-1998, while for USD/GBP, the standard deviation is almost identical in both five-year periods. In contrast, USD/JPY is less volatile in 1999-2003 than in the previous 5-year period. Skewness and kurtosis values for the exchange rates and the results of the normality tests suggest that for all the exchange rates, the distribution of the return series is closer to normality in 1999-2003 period, compared to 1994-1998 period. For all the exchange rates, except USD/EUR, skewness is not significantly different from zero in 1999-2003. In 1994-1998 period, none of the exchange rates had skewness not significantly different from zero. Although, no currency pair has the kurtosis equal to zero even in 1999-2003 period, low kurtosis values in the later sub-period, suggest that the distribution of the return series approached normality and that returns have become more homoscedastic. The results of the normality tests still provide an evidence of non-normality in both sub periods, but there are indications that the distribution of return series is closer to normality in 1999-2003 period than in 1994-1998, for all exchange rates. The Chi square normality test provides the values of above 200 in the period of 1994-1998, and around 30 in the more recent five-year sub-period. This is the indication of FX markets becoming more efficient in the recent years.

Figures 3 and 4 shows a graphical representation of average daily FX returns by day of the week and months of a year, respectively. Average FX return is highest

[9] according to non-parametric Mann-Whitney test

on Thursdays for all currency pairs, and is equal to 0.065 for USD/GBP, USD/CHF and USD/JPY. The lowest FX returns are observed on Fridays for all exchange rates, apart from USD/EUR. The FX rate of USD/JPY has the lowest average daily change of negative 0.081. The average daily changes in the FX prices are highest in September, followed by December, while the lowest FX returns are observed in January and November. Both maximum (0.107) and minimum (-0.086) daily changes are reported for USD/CHF currency pair.

3.2. FX Implied Volatilities

It is the change in the implied volatility that is important because such changes generate changes in option prices, which in turn, produce trading profits and losses. Academics and practitioners are more interested in the changes or innovations to the expected volatility. Besides, the use of the implied volatility changes as opposed to the absolute values is preferable, given non-stationary nature of the implied volatility data. To avoid the problem of non-normality and heteroscedasticity of the regression residuals we use log transformation in our estimation. We use log changes as opposed to the first difference of the change, given that the log transformation is the most effective in improving the model when the distribution of the error variable is positively skewed, which is the case with our sample. The use of the log transformation is also consistent with the existing literature (see Ederington and Lee, 1996 and Giot, 2005). Another advantage of using log transformation is that the log transformation effectively eliminates the extreme outliers, resulting in more robust regression coefficients (Andersen and Bollerslev, 1998).

The lognormal changes in the implied volatilities are calculated in equation 3-2:

$$V_{x,t} = \ln(IV_{x,t}/IV_{x,t-1}) \qquad \textbf{(3-2)}$$

where,

$V_{x,t}$ – the lognormal change in the implied volatility of the exchange rate x on day t
$IV_{x,t}$ – the implied volatility of the exchange rate x on day t
$IV_{x,t-1}$ - the implied volatility of the exchange rate x on day $t-1$

In Section 3.2.1, we justify the choice of our data, while section 3.2.2 provides a summary of descriptive statistics for implied volatilities.

3.2.1. Implied Volatilities Data

The volatility data in this research includes daily quotes of the implied volatilities of four major exchange rates estimated from options with one month to maturity. The ability of the implied volatility to represent the market's estimate of the underlying asset's average annualized volatility of returns over option's life is most accurate for at-the-money options with the expiry date of at least 3 weeks (Feinstein, 1989 and Heynen et. al, 1994). Shorter-term options are mainly used as hedging tools by market makers, resulting in the volatilities of such options being very variable and higher than those of longer-term options. At-the-money options are also more sensitive to the changes in volatility than are in-the-money and out-of-the-money options. The use of closing prices of at-the-money options closely approximates the synchronous data as volume tends to be concentrated in these contracts (Barone-Adesi and Cyr, 1994).

Currency implied volatilities used in our study are drawn from over-the-counter (OTC) markets, which are considerably more liquid than currency futures options. Castren and Mazzotta (2005) showed that since the trading volume in OTC options is often much larger than in the corresponding market traded contracts, the underlying liquidity on OTC quotes is deeper, which makes the OTC quotes a more reliable source for information extraction. Christensen et. al (2001) mentioned that OTC prices are quoted daily with fixed "moneyness" (the distance between the forward rate and the option's strike price) as opposed to exchange-traded options, which have fixed strike prices and therefore time-varying moneyness as the forward exchange rate changes. This makes OTC options data being of superior quality, in terms of forecasting properties, relative to exchange-traded options.

There are several types of errors, which arise when the implied volatility series quoted via data providers like Reuters or Telerate are used. First, the quotes come from many contributors in an irregular sequence. Second, the market makers tend to publish new quotes in order to attract traders in the direction in which they want to trade. Thirdly, the main local markets can have different trading habits (e.g., different average volumes per transaction or bid-ask spreads) even if their active periods overlap. In addition, there are transmission delays varying from few seconds up to few minutes. There are also transmission breakdowns or other failures, which tend to arise due to human and technical errors in the communication channels that cause database holes. Fortunately, most of these types of error can cause problems when intraday data is used, especially for the very short-term movements, but are unlikely to significantly impact the results when daily quotes are employed.

Besides, analyzing the risk and return relation at longer horizons, like ten years, tends to produce more accurate results, given the empirical evidence of greater returns predictability at longer horizons. At short horizons, the true long run risk and return relation could be obscured by short term noise, which might be caused by various factors, such as the agents trading for portfolio rebalance, transaction costs considerations or unexpected immediate consumptions needs, as suggested by Daniel and Marshall (1997). Harison and Zhang (1998) concluded that at shorter intervals, no meaningful risk and return relation emerges.

3.2.2. Descriptive Statistics for Implied Volatilities

Table 4 reports the descriptive statistics for the daily changes of implied volatilities for major exchange rates (no extreme observations are omitted from the data set to be consistent with the existing literature). Due to data availability, out of possible 3650 observations, in the ascending order, 3135 observations have been obtained for USD/JPY, 3066 for USD/EUR, 2746 for USD/GBP and 2714 for USD/CHF. The mean volatility changes are negative for all the exchange rates, but USD/GBP, ranging from negative 0.0073 for USD/JPY to positive 0.0117 for USD/GBP. The standard deviation of volatility change range from 0.0359 for USD/EUR to 0.0704 for USD/CHF.

Barone-Adesi and Cyr (1994) suggested that the presence of an obvious outlier, such as October 1987 stock market crash, in the time series of the implied volatility estimates can result in significant identification errors in the form of the noise component of the model used to test for volatility seasonality patterns. Therefore, we check the robustness of the results to the exclusion of the outliers, which are defined as those exceeding 2.33 standard deviations (0.99th percentile) or 3.09 standard deviations (0.999th percentile) in magnitude. The preliminary analysis suggests that the regression estimates are affected, though not significantly, by the exclusion of the outliers from the data set. To avoid biased regression coefficients resulting from the outliers, the heteroscedasticity and autocorrelation consistent regression coefficients' standard errors and t-statistics are re-estimated using Andrews (1991).

Skewness and kurtosis of lognormal volatility changes are all positive, significantly different from zero, and well outside a normality range. This suggests that the data distribution is asymmetric at 95% confidence level, skewed right (right tail is heavier than the left tail), and have a distinct peak near the mean and heavy tails. Similar results have been obtained by Andersen et. al (2003) and Pohlmeier (2005) for the FX realized volatility. The results of the normality and asymmetric tests presented in the Table 4 provide a further evidence of non-normality of the implied volatility changes in the major exchange rates. Significant kurtosis suggests that the data is heteroscedastic and has non-uniform variance.

As per Table 5, the mean volatility changes in 1994-1998 sample period are positive for USD/GBP (0.0327) and USD/JPY (0.0395) and negative for USD/EUR (-0.0093) and USD/CHF (-0.0003). In 1999-2003 sample period, the average volatility changes declines for all currency pairs and become negative for all currency pairs apart from USD/EUR, which has a mean volatility change of 0.0012. The results of non-parametric[10] Mann-Whitney test, also known as the two-sample Wilcoxon rank sum test suggests that the difference between the population medians in two sub-periods is statistically significant[11] for USD/GBP, USD/EUR and USD/CHF. Finally, skewness and kurtosis values suggest that normality of the data distribution can be rejected at 95% confidence level for all exchange rates.

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[10] since data distribution is not normal, non parametric test has been used instead of t test
[11] at 90% confidence level

Table 6 reports the descriptive statistics for volatility changes for each day of the week, including Saturdays and Sundays, while Figure 5 is the graphical representation of the mean results. We do have Saturdays and Sundays in our sample, because of the 24-hour nature of the FX market and the difference in world time zones. For example, some Middle Eastern markets are open on Saturday and Sunday, while early Monday morning activity in East Asian markets coincides with Sunday nights in GMT. The sample is fairly evenly distributed across the business days of the week, however relatively smaller number of observations have been obtained for Saturday and Sunday.

The largest positive volatility changes are observed on Monday for all exchanges, apart from USD/JPY, for which the highest volatility is observed on Sunday, followed by Monday. High Monday volatility is consistent with the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), which implies that since traders use private information accumulated during the weekend before the information is publicly disseminated, volatility is significant on Monday. High Sunday volatility reported for USD/JPY could also be explained by the private information hypothesis, since the early Monday morning activity in East Asian markets coincide with Sunday nights in GMT, and therefore, the impact of the private information based trading in USD/JPY is spread over Sunday and Monday. On average, the lowest volatilities are observed on Thursday and Friday for all four exchange rates. Given that the majority of the US scheduled announcements are released on Thursday and Friday, these results are consistent with Ederington and Lee (1996), who suggested that the uncertainty, measured by the implied volatility, would be high prior to the release of the scheduled announcements and would fall following the release, as the source of uncertainty is resolved with the release of the announcements. Table 6 also reports skewness and excess kurtosis for the volatility changes of each exchange rate by day of the week. All sample distributions exhibit high levels of kurtosis, indicating that these distributions have thicker tails than normal distributions, are heteroscedastic and has non-uniform variance. Although in most cases, sample distributions are positively skewed, in some occasions, they display negative skewness. However, all sample distributions exhibit skewness that is well outside a normality range, suggesting that they are nonsymmetric.

Table 7 reports the descriptive statistics for volatility changes for each month of the year, while Figure 6 is the graphical representation of the mean results. As in the case with the days of the week, the sample is fairly evenly distributed across the months of the year. Implied volatility changes are relatively insignificant in the first half of the year, but tend to be more volatile in the second half. Volatility is insignificant in the first two months of the year, but tends to drop in March and April. The only exemption is USD/CHF, for which March (0.367) coincides with the second largest increase in the implied volatility. After 3 months of relatively low activity, implied volatility increases in August and September, with all exchange rates exhibiting positive implied volatility changes, before falling in October and November. The largest negative volatility change is observed in October for USD/EUR (-0.337) and USD/JPY (-0.635) and in November for USD/CHF (-0.383). Finally, the largest positive volatility changes are observed in December for USD/EUR (0.397), USD/GBP (0.423) and USD/JPY (0.463). For USD/CHF, the mean implied volatility change in December (0.337) is the third largest increase after August (0.378) and September (0.382). Significant implied volatility in December could be explained by the turn of the year effect, and is consistent with Rogalski and Maloney (1989), who provided an evidence of the increasing implied volatilities prior to the turn of the year in the equity market. Rogalski and Maloney (1989) explained this by the fact that the market participants anticipate the market to be volatile prior to the turn of the year. Skewness and kurtosis values are similar to those reported for the entire sample, suggesting that all sample distributions are leptokurtic and skewed.

3.3. News Announcements and Holidays

Section 3.3.1 discusses the macroeconomic data on the US news announcements, while section 3.3.2 examines the data on the BOJ interventions. Section 3.3.3 focuses on the holidays.

3.3.1. US Macroeconomic News Announcements

The data on the US macroeconomic variables for the period of 1998 – 2003 has been obtained from http://www.finance.yahoo.com. The data includes the day and time of the announcement, the forecasted value and the actual value released. A list of the sixteen scheduled announcements used in this study is provided in Table 8. Four of the macroeconomic announcements tested in this study provide information on consumer demand (trade balance, retail sales, auto sales and consumer confidence) and another four are inflationary indicators (consumer price index (CPI), producers' price index (PPI), unemployment rate and non-farm payrolls). The remaining six macroeconomic indicators covered in this study provide information about economic growth - construction spending report, housing starts, durable goods, Gross Domestic Product, the index of industrial production and the leading indicators.

Table 9 shows the release dates for US macroeconomic indicators. Some indicators, like PPI and CPI[12] have the same information content, and therefore are related in some way. The existance of the correlation between the independent variables creates a multicollinearity condition, resulting in the inaccurate results due to the large sampling variability of the estimated regression coefficients. In order to avoid the problem of multicollinearity, the impact of the announcements on the FX implied volatility is analyzed separately.

In addition to the scheduled macroeconomic announcements we consider the impact of FOMC minutes on the FX volatility (FOMC meets once in eight weeks

[12] The relationship between CPI and PPI releases and their impact on the FX volatility is discussed later in the study.

and decides on the official US interest rate). In the period of 1998-2003 there were twenty-five scheduled FOMC meetings. The study will also be extended to the situations when the official interest rates do change, as the result of both scheduled and unscheduled FOMC meetings. There were twenty-three occasions in 1998-2003 period when FOMC announced a new official interest rate.

3.3.2. Bank of Japan (BOJ) Interventions

Given that the Fed revised the intervention policy, resulting in only two interventions in the second half of 1990s, the dates of BOJ intervention rather than US central bank interventions have been used in this study. BOJ has the reputation of being the most active central bank in the FX market among G7 central banks. The data13 on the interventions conducted by the BOJ has been obtained from the official web site of the Ministry of Finance of Japan. BOJ conducted interventions on one hundred and seventeen days in 1998-2003 period (Figure 7). Only the first three of these interventions involve the purchase of Yen, and the remaining one hundred and fourteen interventions involve the sale of Yen against US dollar and Euro. BOJ's attempts to prevent appreciation of the Yen are explained by the negative impact of strong Yen on the Japanese exports. During eleven interventions the intervention involved Euro, and during the remaining one hundred and six interventions the Yen was exchanged for US dollar14.

3.3.3. Holidays

We study the behavior of the FX prices and implied volatilities around the official holidays in the United Kingdom, United States of America, Japan,

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[13] Although, it is possible to use the timings of the newswire reports of those operations, as proposed by Dominguez (2004), this approach presents drawbacks in that it is unclear whether the timing of the reports is consistent with that of the actual operations. Using real time data of the interventions of the Bank of Swiss, Fischer (2005) showed that significant discrepancies in terms of timings emerge between Reuters reports of the interventions and the actual operations of the Swiss monetary authorities.

14 Prior to the introduction of euro, BOJ preferred US dollar as the counterparty for Yen when conducting interventions (Frenkel et. al, 2003). The introduction of euro and the tendency of the BOJ to conduct interventions in cooperation with other major central banks, including European Central Bank caused the BOJ to start buying Euros instead of US Dollars.

Switzerland and Germany. The names and dates of the official holidays used in this study is provided in Table 10.

3.4. Summary

In this chapter we summarized and described the data that forms the basis of the empirical testing in chapters 7 through 10. We discuss the data on the FX return series and implied volatilities. We estimate log changes in the FX prices and implied volatilities to avoid the problem of non-normality, autocorrelation and heteroscedasticity of the regression residuals and to eliminate the extreme outliers, resulting in more robust regression coefficients.

We provide description of the data for pre and post euro sample periods, and show that average daily return is higher in post euro period for all exchange rates, apart from USD/GBP, while average implied volatility change is higher in pre euro period for all currency pairs, apart from USD/EUR. We also provide descriptive statistics by day of the week and month of the year, showing that FX returns are higher on Thursdays and in the months of September and December, and low on Fridays and in the months of November and January. Implied volatility was found to be high on Mondays and in December and low during the second half of a week and in the months of October and November.

We also describe our data sample on the US macroeconomic announcements and Bank of Japan interventions. We provide definition of each macroeconomic indicator and summarize the release dates for the indicators. We obtain the data on the BOJ interventions from the official web site of the Ministry of Finance of Japan. The use of the official intervention data instead of news records taken from Reuters increases the accuracy of our study. The data described here forms the main basis of the empirical testing, which is the topic of the next chapter.

Table 3-1. Descriptive Statistics for FX Return Series

	USD/EUR	USD/GBP	USD/CHF	USD/JPY
Mean	0.0048	0.0074	0.0071	0.0016
Variance	0.3556	0.2421	0.4850	0.5530
Standard Deviation	0.5964	0.4921	0.6964	0.7437
Excess Kurtosis	2.1891	1.6341	2.1244	8.9514
Skewness	0.3388	-0.0522	0.1956	0.9869
Minimum	-2.4915	-2.7063	-3.7740	-3.9549
Maximum	3.3210	2.0752	3.7126	7.6773
Normality Test: Chi^2(2)	263.81	189.59	276.80	1317.0
Observations	2555	2555	2555	2555

The table reports mean, variance, standard deviation, and the values of the minimum and maximum observations for the returns on the four major exchange rates. It also reports the skewness and kurtosis values, as well as the results of the normality test. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for 10 years from January 1994 through December 2003. The daily 2555 observations are used. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Table 3-2. Correlation Matrix

	USD/EUR	USD/GBP	USD/CHF	USD/JPY
USD/EUR	1.0000	0.51802	0.72788	0.32173
USD/GBP	0.51802	1.0000	0.57425	0.26714
USD/CHF	0.72788	0.57425	1.0000	0.42162
USD/JPY	0.32173	0.26714	0.42162	1.0000

The table reports the correlation coefficients among the exchange rates. The coefficients are all positive and significantly different from zero, ranging from 0.27 to 0.73. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for 10 years from January 1994 through December 2003.

Table 3-3. Descriptive Statistics for Exchange Rates in 1994-1999 and 1999-2004

	USD/EUR		USD/GBP	
	1994-1998	1999-2003	1994-1998	1999-2003
Observations	1259	1259	1259	1259
Mean	0.0039	0.0057	0.0091	0.0056
Standard Deviation	0.5632	0.6271	0.4937	0.4907
Kurtosis	3.8304	1.0673	2.4907	0.7937
Skewness	0.4284	0.2729	-0.108	0.0029
Minimum	-2.4915	-2.266	-2.7063	-1.655
Maximum	3.0481	3.321	2.0752	1.8263
Normality Test	299.66	185.4	264.25	473.21
	USD/CHF		USD/JPY	
	1994-1998	1999-2003	1994-1998	1999-2003
Observations	1296	1296	1296	1296
Mean	0.0063	0.0079	-0.0013	0.0044
Standard Deviation	0.7051	0.6882	0.825	0.6554
Kurtosis	3.3062	0.8677	10.7022	2.7868
Skewness	0.2898	0.0975	1.4907	-0.0349
Minimum	-3.774	-2.3176	-3.4566	-3.9549
Maximum	3.7126	2.6925	7.6773	2.8463
Normality Test	46.35	28.86	33.66	229.6

The table reports mean, standard deviation, and the values of the minimum and maximum observations for the returns on the four major exchange rates. It also reports the skewness and kurtosis values, as well as the results of the normality test. The exchange rates are the daily rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for two five-year sub-periods from January 1994 through December 1998 and from January 1999 through December 2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Table 3-4. Data Description for Implied Volatility Series

	USD/EUR	USD/GBP	USD/CHF	USD/JPY
Observations	3066	2746	2714	3135
Mean*	-0.0038	0.0117	-0.0040	-0.0073
Standard Deviation	0.0359	0.0692	0.0704	0.0468
Skewness	1.1587	0.7277	0.244	1.1765
Excess Kurtosis	6.566	57.13	13.958	9.1321
Minimum	-0.1732	-0.7215	-0.6027	-0.2755
Maximum	0.2723	0.7038	0.5923	0.4848
Normality test	725.87**	18133**	4430.3**	1311.4**

* *mean volatility changes are multiplied by 100*
** *normality rejected*

The table reports mean, standard deviation, and the values of the minimum and maximum observations for the changes in implied volatilities of four major exchange rates. It also reports the skewness and kurtosis values, as well as the results of the normality test. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for 10 years from January 1994 through December 2003. The daily observations, ranging from 2714 to 3135, have been used.

Table 3-5. Data Description for Implied Volatility Series in 1994-1998 and 1999-2003 periods

	USD/EUR		USD/GBP	
	1994-1998	**1999-2003**	**1994-1998**	**1999-2003**
Observations	1437	1629	1206	1540
Mean*	- 0.0093	0.0012	0.0327	-0.0048
Standard Deviation	0.0404	0.0314	0.0938	0.0405
Skewness	1.2753	0.8677	0.5973	0.6009
Excess Kurtosis	6.0994	5.7947	34.1510	72.3520
Minimum	-0.1733	-0.1503	-0.7215	-0.6080
Maximum	0.2723	0.2455	0.7038	0.6080
	USD/CHF		**USD/JPY**	
	1994-1998	**1999-2003**	**1994-1998**	**1999-2003**
Observations	1217	1497	1482	1653
Mean*	-0.0003	-0.0146	0.0395	-0.0971
Standard Deviation	0.0883	0.0528	0.0510	0.0467
Skewness	0.1814	0.3560	1.1538	-2.4073
Excess Kurtosis	11.0650	5.3184	9.1065	63.3810
Minimum	-0.6027	-0.2423	-0.2755	-0.8252
Maximum	0.5924	0.3090	0.4849	0.3472

* *mean volatility changes are multiplied by 100*

The table reports mean, standard deviation, skewness and kurtosis values and the values of the minimum and maximum observations for the changes in implied volatilities of four major exchange rates. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for two five-year sub-periods from January 1994 through December 1998 and from January 1999 through December 2003.

Table 3-6. Summary Statistics by Day of the Week

	MON	TUE	WED	THU	FRI	SAT	SUN
USD/EUR							
Observations	508	506	507	505	501	134	404
Mean*	1.0693	-0.0444	0.0177	-0.4830	-0.4910	-0.1540	-0.0781
Standard Deviation	0.0411	0.0376	0.0392	0.0388	0.0312	0.0164	0.0281
Skewness	1.0969	1.4012	1.2482	0.7996	0.9045	-1.4066	0.8765
Excess Kurtosis	7.2219	7.3103	6.3442	2.3971	4.7427	14.9321	3.4435
USD/GBP							
Observations	491	498	495	492	489	121	160
Mean*	1.0327	1.0189	-0.3855	-0.7791	-0.6642	-0.5368	-0.1155
Standard Deviation	0.0814	0.0770	0.0694	0.0538	0.0661	0.0560	0.0541
Skewness	1.9856	6.2020	-5.6067	-2.9301	-1.4080	-10.5485	9.1552
Excess Kurtosis	45.0928	49.7406	57.5406	37.8598	63.1108	114.3738	102.9749
USD/CHF							
Observations	481	493	490	485	479	124	162
Mean*	1.5184	0.0786	-0.1904	-0.6504	-0.3394	-1.2816	-0.3062
Standard Deviation	0.0800	0.0696	0.0622	0.0652	0.0736	0.0563	0.0745
Skewness	0.8812	0.0933	0.7132	-0.5417	0.7832	-1.0645	-2.8087
Excess Kurtosis	11.5764	18.3490	18.7432	7.3138	7.8521	4.9396	33.2682
USD/JPY							
Observations	508	509	509	508	507	128	451
Mean*	0.5520	-0.1602	-0.2324	-0.4596	-0.2837	-0.0755	0.6642
Standard Deviation	0.0516	0.0509	0.0487	0.0544	0.0414	0.0115	0.0355
Skewness	0.5088	1.0722	0.8322	1.9143	1.0350	1.6746	1.9456
Excess Kurtosis	6.5459	7.6806	3.4986	14.0806	5.3166	13.4983	9.7749

* *mean volatility changes are multiplied by 100*

The table reports mean, standard deviation, skewness and kurtosis for the implied volatility changes of four major exchange rates by days of the week. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for 10 years from January 1994 through December 2003.

Table 3-7. Summary Statistics by Month of the Year

USD/EUR												
Observations	267	251	263	253	276	256	257	264	242	242	241	254
Mean	-0.0692	-0.0237	0.0119	-0.1222	0.1008	-0.198	0.1262	0.1542	0.2178	-0.3372	-0.338	0.3973
Standard Deviation	0.0369	0.0330	0.0352	0.0396	0.0336	0.0308	0.0367	0.0340	0.0417	0.0400	0.0331	0.0357
Skewness	0.7154	0.5357	0.8765	1.2331	0.6929	0.3189	2.3803	1.2689	1.3928	1.0699	0.0578	2.4286
Excess Kurtosis	2.0325	9.1788	2.8894	5.9914	1.8798	1.9874	13.6537	5.0511	7.0449	6.5149	2.2022	14.2521
USD/GBP												
Observations	236	231	232	211	236	230	232	241	217	226	216	238
Mean	-0.1026	0.1901	-0.3979	-0.2131	0.0205	0.3316	-0.2117	0.1852	0.1744	-0.2810	-0.008	0.4231
Standard Deviation	0.0400	0.1137	0.1504	0.0390	0.0378	0.0442	0.0345	0.0350	0.0476	0.0703	0.0412	0.0620
Skewness	0.4944	1.1652	-0.0255	0.9175	0.9850	1.3592	0.5558	0.9506	1.7136	0.3879	1.3313	3.0939
Excess Kurtosis	9.5644	25.7788	16.5629	3.0082	4.2630	6.0903	2.0871	6.9398	7.0126	49.3962	6.7643	30.0489
USD/CHF												
Observations	237	229	215	205	241	232	237	241	202	216	215	244
Mean	0.0246	0.0628	-0.2637	-0.0375	-0.124	-0.082	-0.2515	0.3822	0.3787	-0.1225	-0.382	0.3375
Standard Deviation	0.0654	0.0795	0.0716	0.0630	0.0642	0.0469	0.0737	0.0825	0.0882	0.0731	0.0708	0.0596
Skewness	0.4796	0.5132	0.2091	-0.2723	0.7699	0.4485	-2.1486	1.6559	-0.0499	0.5340	0.0215	0.2060
Excess Kurtosis	5.4412	11.5064	9.7492	9.9756	3.9910	3.8007	24.3274	21.8355	18.1675	2.2445	4.4202	8.4613
USD/JPY												
Observations	270	253	263	257	275	262	263	268	263	255	245	261
Mean	-0.1268	0.1360	0.3668	-0.5755	-0.168	0.1301	0.0982	0.0453	0.3638	-0.6350	-0.212	0.4632
Standard Deviation	0.0400	0.0408	0.0474	0.0421	0.0463	0.0563	0.0432	0.0476	0.0569	0.0558	0.0385	0.0406
Skewness	0.2475	-0.0330	1.5403	0.2716	0.6234	1.1127	0.9469	1.5581	1.3660	2.3734	0.9363	0.6327
Excess Kurtosis	3.0726	4.9490	6.7145	2.7300	2.9669	5.3039	3.4012	7.2974	8.3786	25.2165	3.1354	5.0225

** mean volatility changes are multiplied by 100*

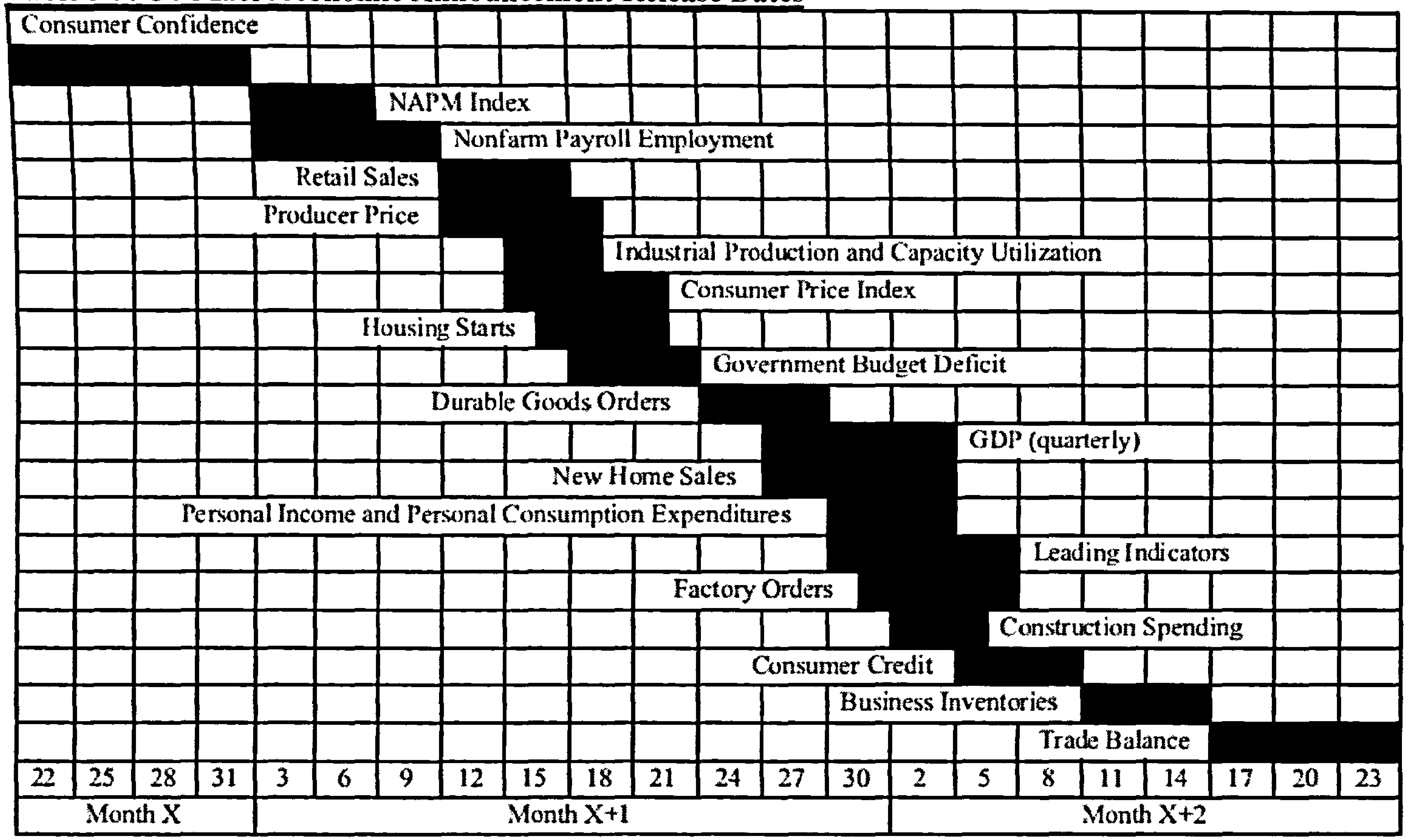
The table reports mean, standard deviation, skewness and kurtosis for the implied volatility changes of four major exchange rates by months of the year. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for 10 years from January 1994 through December 2003.

Table 3-8. Macroeconomic Indicators

ANNOUNCEMENT	EXPLANATION
Trade Balance	measures by how much national exports exceed national imports
Employment	unemployment rate
Consumer Price Index (CPI)	measures the change in the cost of a bundle of consumer goods and services in another sense the change in the cost of living in most American families
Producer Price Index (PPI)	measures the average level of prices of a fixed basket of goods received in primary markets by producers
Retail Sales	measures the total receipts of retail stores
Durable Goods Orders	measures how much people are spending on long-term purchases (products that are expected to last more than three years)
Construction Spending	measures the total amount of spending in the U.S. on all types of construction
Gross Domestic Product	advanced, preliminary and final figures for Gross Domestic Product
Current Account	measures amounts by which a government's spending exceeds its income
Auto Sales	the number of cars sold during a particular ten-day
Beige Book	summary of commentary on current economic conditions by Federal Reserve District
Industrial Production	the total physical output of US factory and mines
Leading Indicators	an indicator to forecast the strengths of the economy in the future
Non-farm Payroll	Counts the number of paid employees working part-time or full-time in the nation's business and government establishments.
Housing Starts	measure of the number of residential units on which construction is begun each month
Consumer Confidence	measures how confident consumers feel about the state of the economy and their spending power

The table provides the basic description for the main sixteen US macroeconomic indicators

Table 3-9. US Macroeconomic Announcement Release Dates



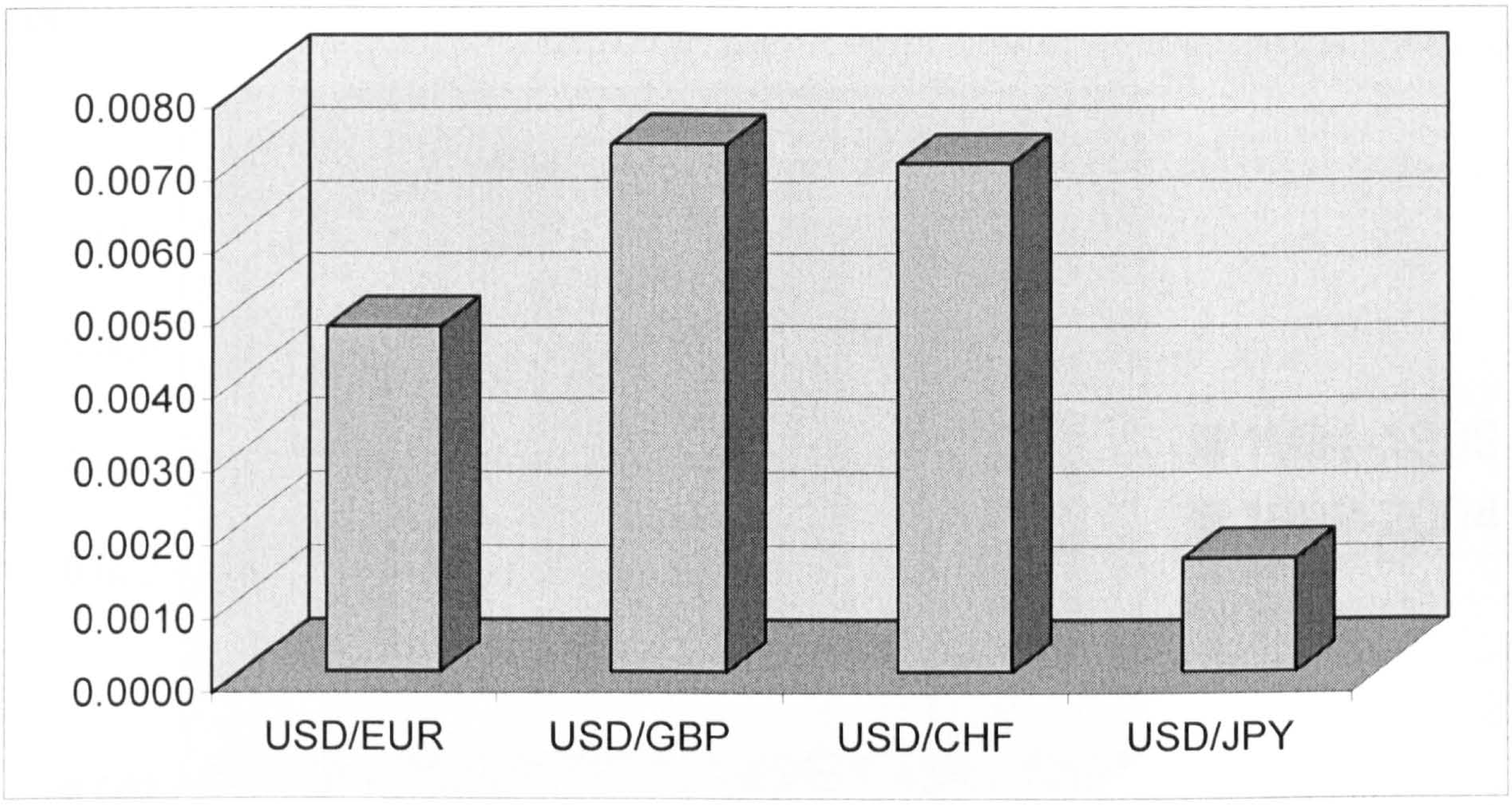
For example, March (month X) consumer credit data are announced between May (month X+2) 5 and May 10. GDP data are special, because they are released only quarterly. Hence, the GDP data released in a given month are either advance, preliminary or final depending on whether the month is the first, second or third of the quarter. For example, first quarter Q1 GDP advance data are announced between April (month X+1) 27 and May 4, first quarter GDP preliminary data are announced between May (month X+2) 27 and June 4, and first quarter GDP final data are announced between June (month X+3) 27 and July 4. The table was also used by Andersen et. al (2003) and is based on 2001 Schedule of Release Dates for Principal Federal Economic Indicators, produced by the U.S. Office of Management and Budget and available at http://clinton4.nara.gov/textonly/OMB/pubpress/pei2001.html.

Table 3-10. Official Holidays

UNITED KINGDOM		GERMANY (EU)	
Date	**Holiday**	**Date**	**Holiday**
January 1st	New Year's Day	January 1st	New Year's Day
January 2nd	New Year's Day	Variable	Good Friday
Variable	Good Friday	Variable	Easter Monday
Variable	Easter Monday	First Monday in May	Labour Day
First Monday in May	May Day	Variable	Ascension Day
Last Monday in May	Spring Day	Variable	Whit Monday
Last Monday in August	Summer	October 3rd	Day of Germany Unity
December 25th	Christmas Day	December 25th	Christmas Day
December 26th	Boxing Day	December 26th	St. Stephen's Day
UNITED STATES		**JAPAN**	
Date	**Holiday**	**Date**	**Holiday**
January 1st	New Year's Day	January 1st	New Year's Day
Third Monday in January	Birthday of M. L. King, Jr.	January 15th	Coming of Age Day
Third Monday in February	Washington's Birthday	February 11th	National Foundation Day
Last Monday in May	Memorial Day	March 21st	Spring Equinox
July 4th	Independence Day	April 29th	Nature Day
First Monday in September	Labor Day	May 3rd	Constitution Day
Second Monday in October	Columbus Day	May 4th	Citizen's Day
November 11th	Veterans Day	May 5th	Children's Day
Fourth Thursday in November	Thanksgiving Day	July 20th	Sea Day
December 25th	Christmas Day	September 15th	Respect for the Aged Day
SWITZERLAND		September 23rd	Autumn Equinox
Date	**Holiday**	October 10th	Sports Day
January 1st	New Year's Day	November 3rd	Culture Day
Variable	Ascension Day	November 23rd	Labour Thanksgiving Day
August 1st	Swiss National Holiday	December 23rd	Emperor's Birthday
December 25th	Christmas Day		

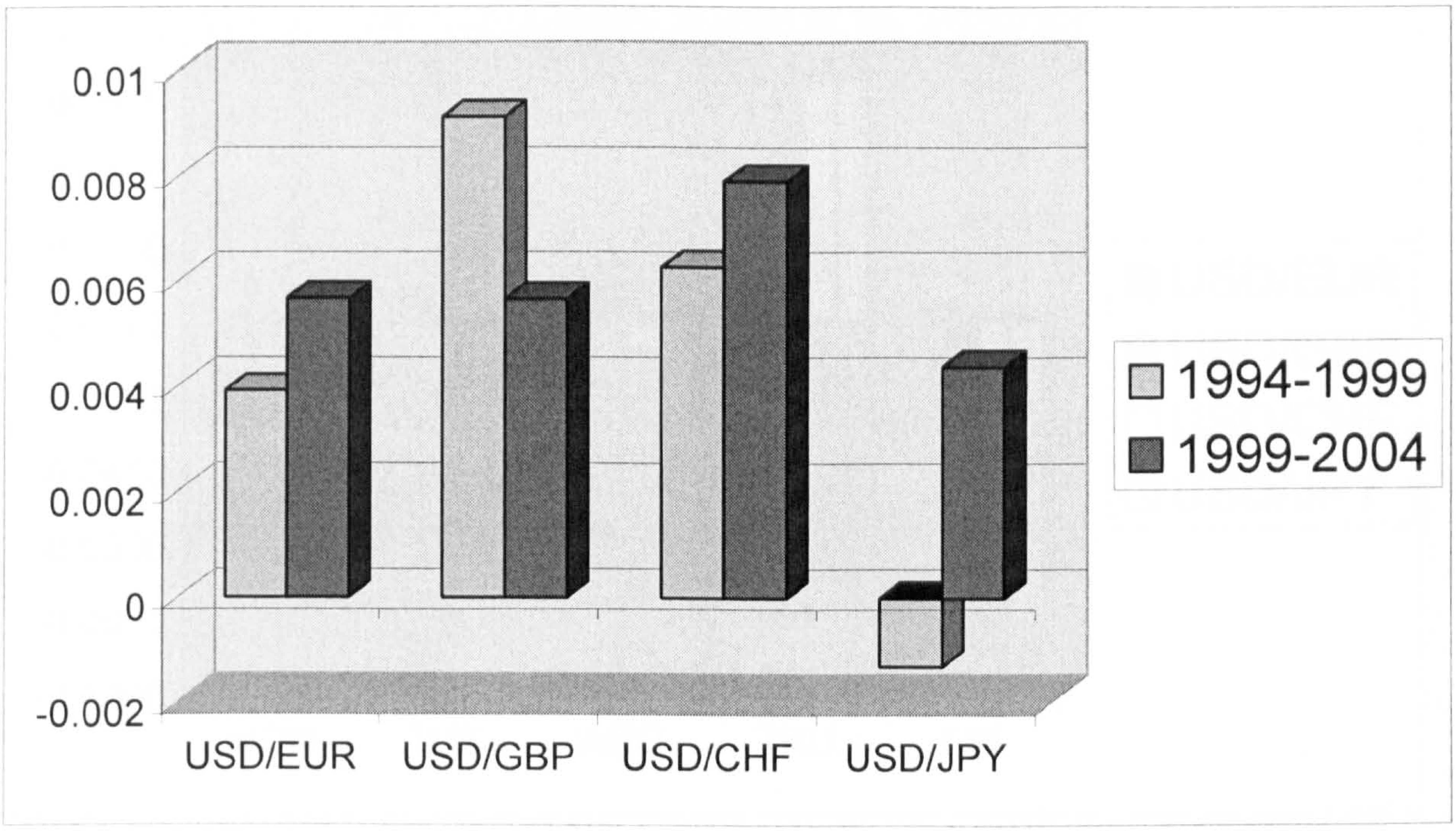
The table summarizes the dates and names of the official holidays in the United Kingdom, United States of America, Japan, Switzerland and Germany

Figure 3-1. Average Daily Rate of Return for 1994-2004



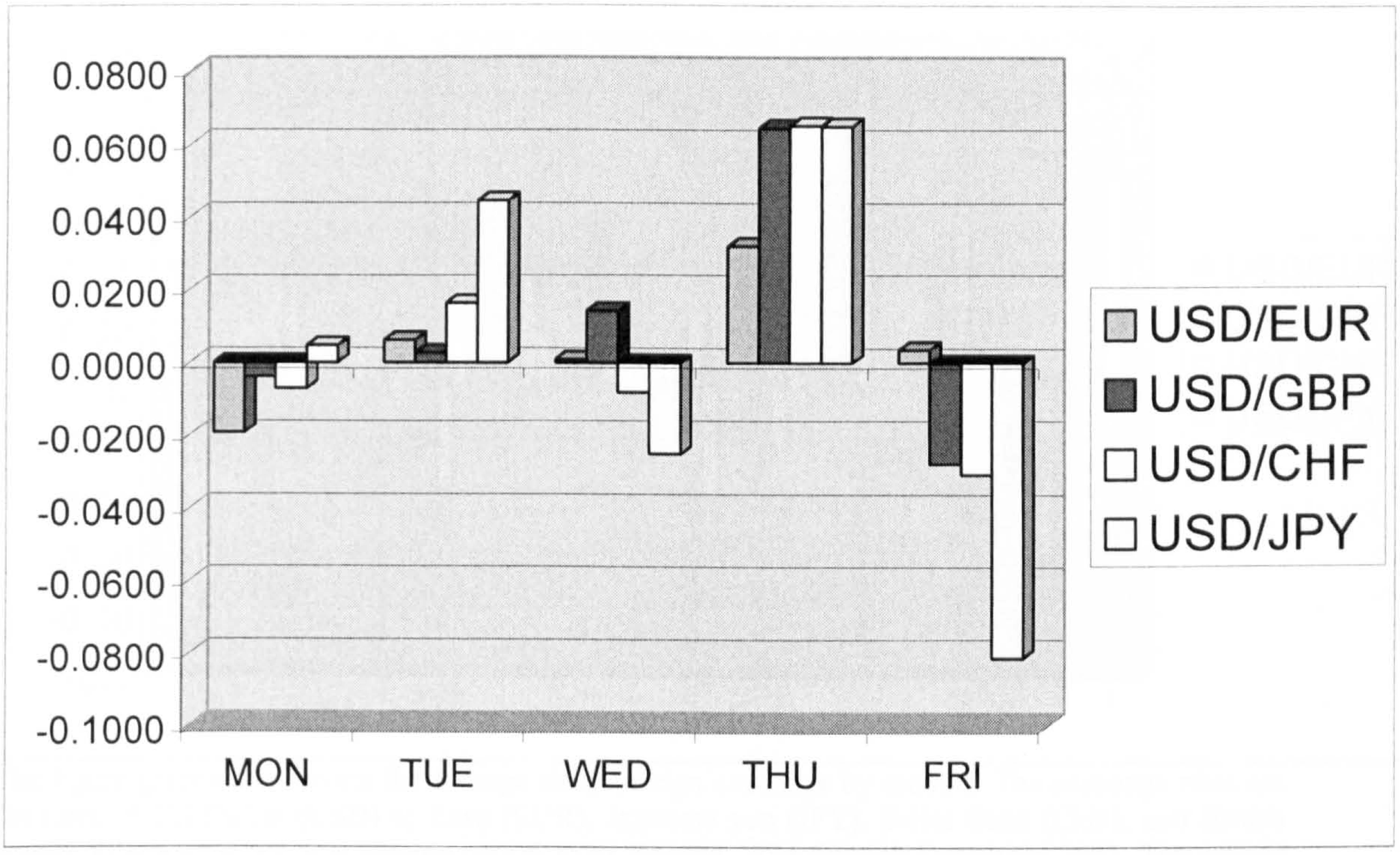
The figure graphically reports the average daily foreign exchange returns. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for 10 years from January 1994 through December 2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Figure 3-2. Average Daily Rates for Exchange Rates in 1994-1999 and 1999-2004



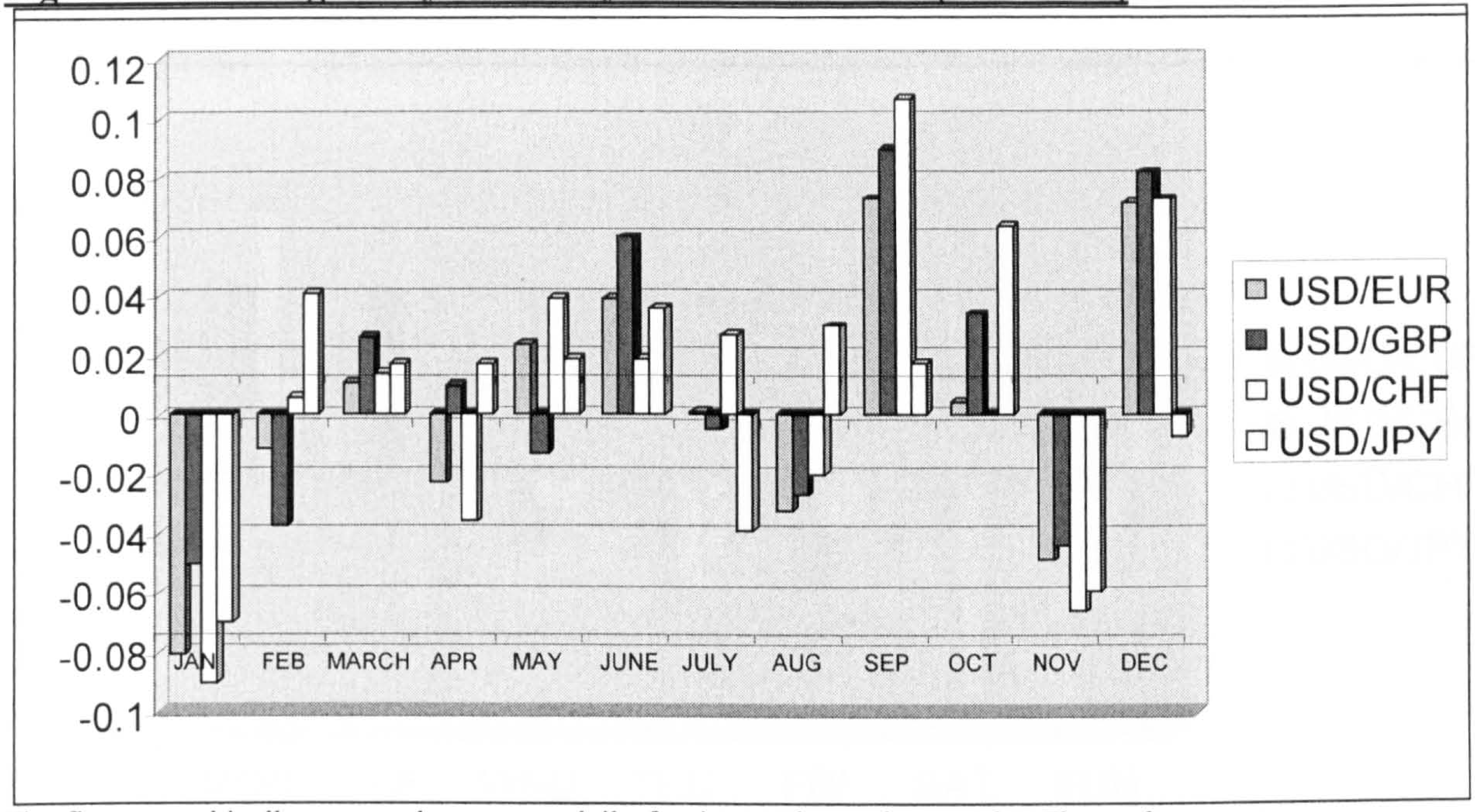
The figure graphically reports the average daily foreign exchange returns. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for two five-year sub-periods from January 1994 through December 1998 and from January 1999 through December 2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Figure 3-3. Average Daily Rates of Return by the Day of the Week (1994-2004)



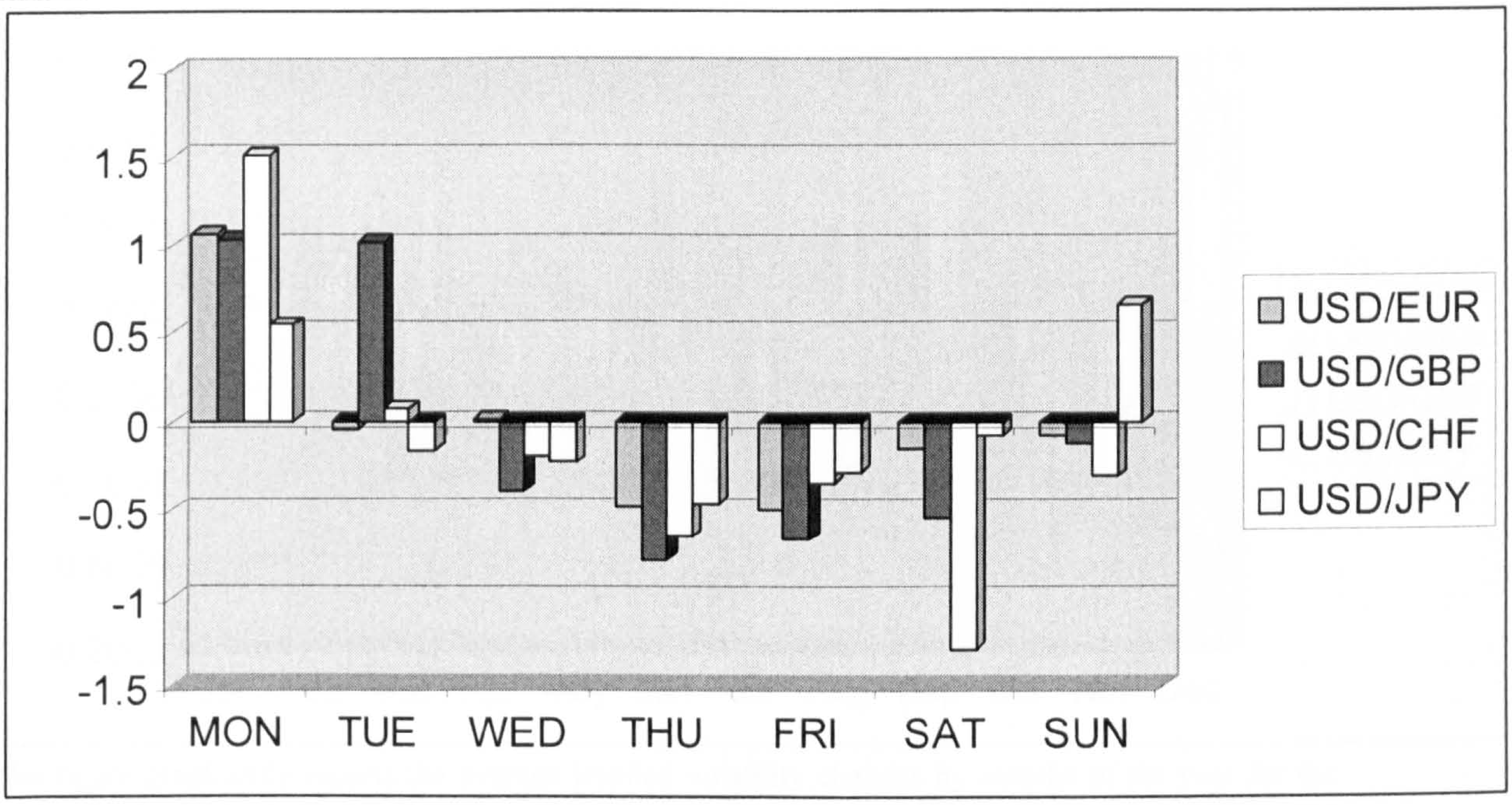
The figure graphically reports the average daily foreign exchange returns by days of the week. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for a sample period of 1994-2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Figure 3-4. Average Daily Return by Months of a Year (1994-2003)



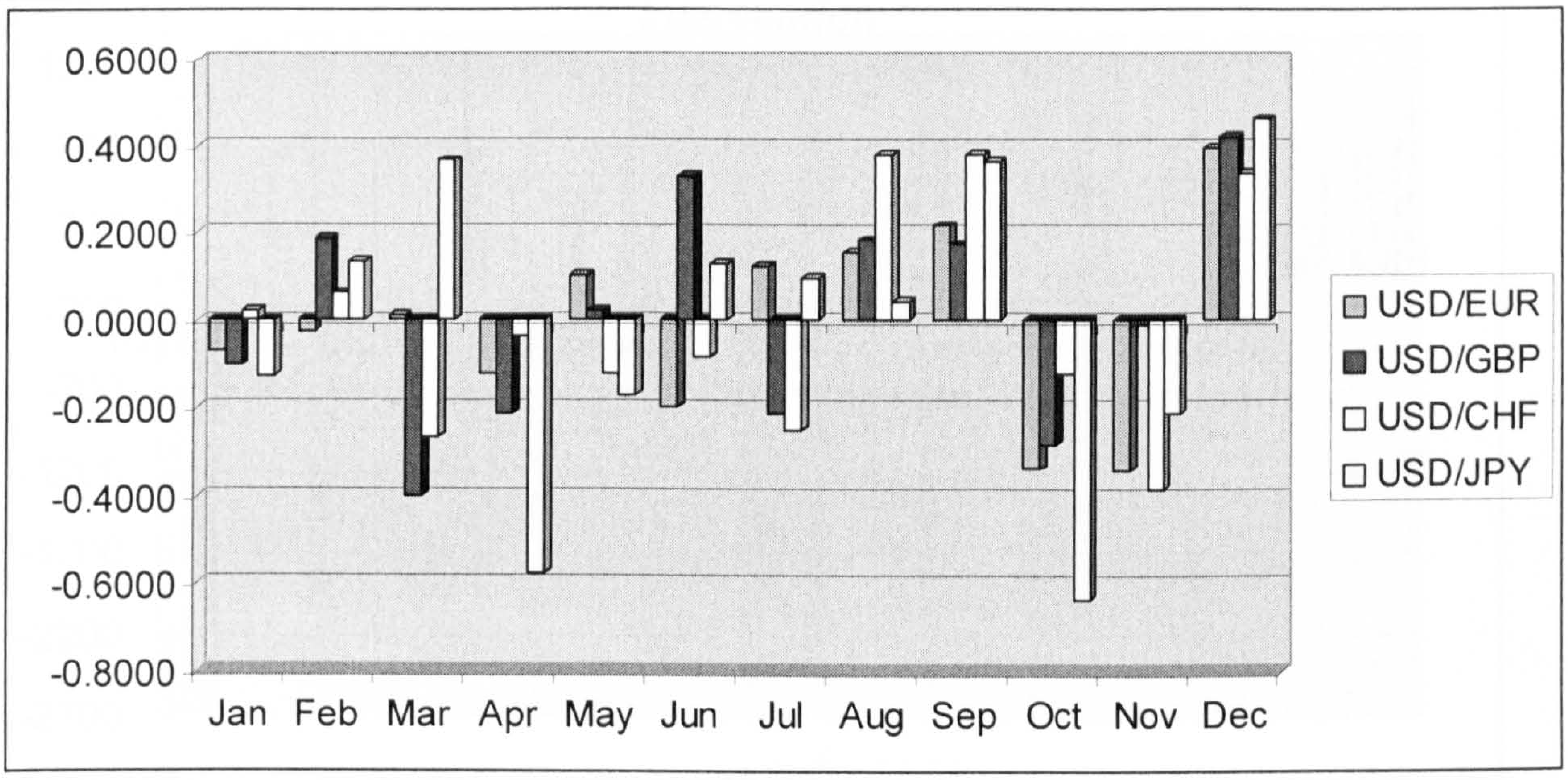
The figure graphically reports the average daily foreign exchange by months. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for a ten-year sample period from January 1994 through December 2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Figure 3-5. Average Implied Volatility Changes by Days of the Week (1994-2003)



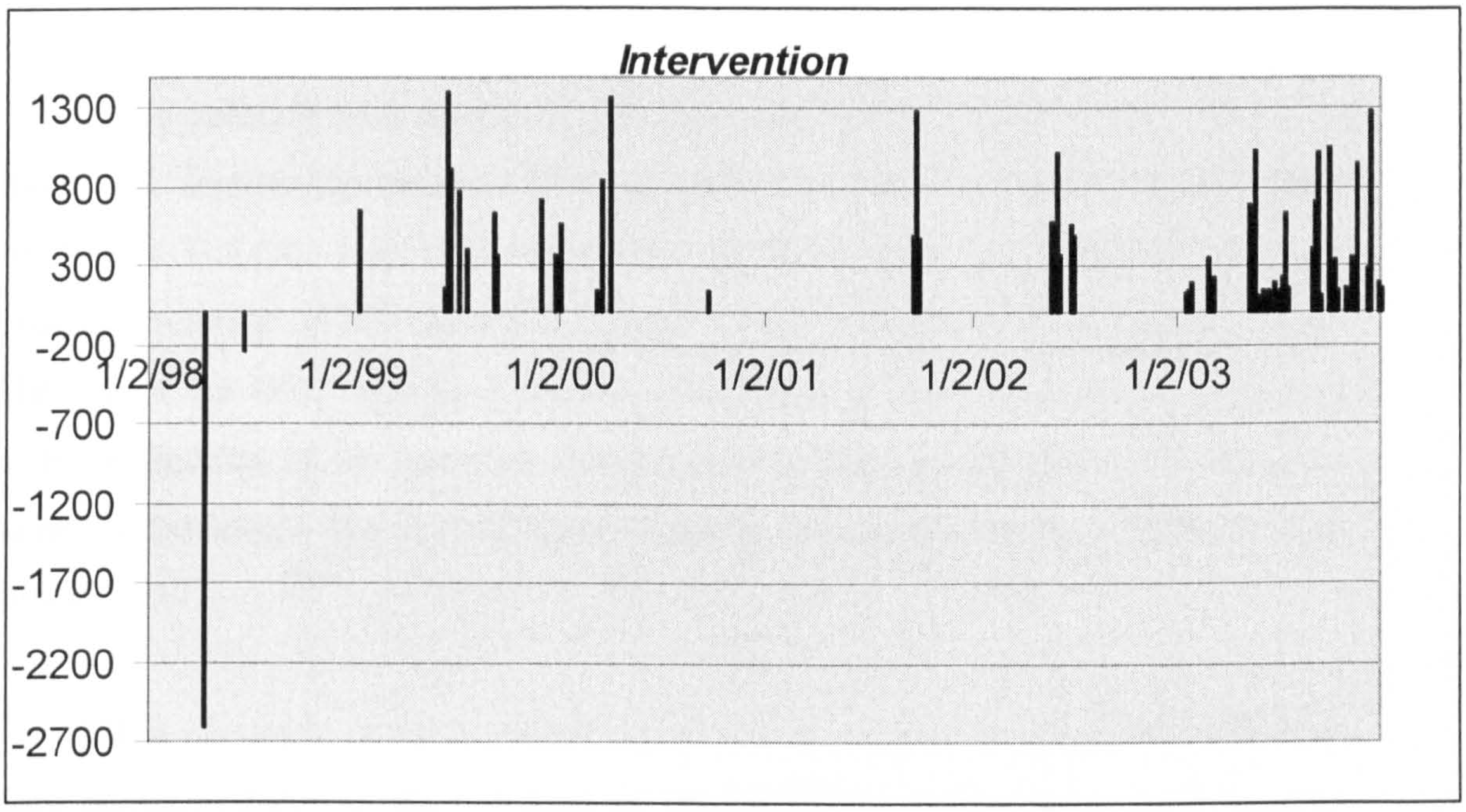
The figure graphically reports the average implied volatility changes by days of the week for the exchange rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for the 10-year period from January 1994 through December 2003. The monthly implied volatility changes are the averages of the daily changes, calculated as $\ln(V_t/V_{t+1})$, where V_t is the close implied volatility on the day t, and V_{t-1} is the close implied volatility on the day t-1.

Figure 3-6. Average Implied Volatility Changes by Months of a Year (1994-2003)



The figure graphically reports the average implied volatility changes by months of the year for the exchange rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for the 10-year period from January 1994 through December 2003. The monthly implied volatility changes are the averages of the daily changes, calculated as $\ln(V_t/V_{t+1})$, where V_t is the close implied volatility on the day t, and V_{t-1} is the close implied volatility on the day t-1.

Figure 3-7. BOJ Interventions Data*



**figures are in billion JPY*

The figure reports central bank interventions, conducted by the BOJ on 117 days in 1998-2003 period. Only the first three of these interventions involve the purchase of Yen, while the remaining 114 interventions involve the sale of Yen against US dollar and Euro. During 11 interventions, the intervention involved Euro (in blue), while during the remaining 106 interventions, Yen was bought or sold for US dollar (in black).

CHAPTER 4. METHODOLOGY AND TESTABLE HYPOTHESIS

The ordinary least squares (OLS) regression model is used to test hypotheses about the seasonality patterns and anomalies in the FX returns and implied volatilities. The OLS regression is probably the most widely used methodology in the existing literature on the seasonality because of its effectiveness and completeness. The use of the OLS regression models also/ makes it easy to compare our results with the findings of the previous studies, most of which were conducted using the same methodology, but for different financial markets and over a different time period.

The accuracy of the standard parametric tests, such as OLS regression has been questioned due to the violation of the basic OLS assumptions (eg normality, heteroscedasticity, autocorrelation). However, as mentioned by Kunkel et. al, parametric tests are robust to mild violations of assumption, especially in large sample like ours. Besides, one study comparing four parametric and nonparametric tests found the patterns of significance and statistical power to be almost identical (Ittenback et. al, 1993).

In order to justify the use of the OLS regression in our study, we address areas of concern below:

- The *normality* test suggests that the regression residuals are not normally distributed, but we note that the large number of observations compensates for the normality assumptions being violated.

- To avoid biased regression coefficients resulting from the outliers, the *heteroscedasticity* and *autocorrelation* consistent regression coefficients' standard errors and t-statistics are re-estimated using Andrews (1991)[1].

[1] Another issue is that, the adjusted *R2sq* on these regressions are low and generally less than 0.10. While these low *R2sq* are not surprising, they do suggest that a large portion of implied volatility changes remains unexplained.

- Throughout the study, we test the *robustness* of the results to address concerns levied by Lindley and Liano (1997) and Sullivan et. al (1998) regarding the robustness of anomaly research.

The results from the hypothesis discussed in this chapter should help to contribute to the existing literature by demonstrating (i) whether patterns documented for the equities and FX futures over 1980s and 1990s exist in the FX cash market over a more recent sample period and (ii) whether the introduction of euro as a single European currency had any significant impact on the return and implied volatility seasonalities, as well as return – implied volatility relation. Throughout the study, we test additional (less general and more specific) hypothesis in order to contribute to the existing literature. For example, we (iii) differentiate between not only positive and negative, but also between large and small returns as well as low and high volatility environment when studying the asymmetric return – volatility relation, (iv) study the FX implied volatility behavior not only on the announcement days, but also during five days prior to and following the announcements, (v) examine and compare the impact of both US and non US holidays on the FX market and (vi) conduct additional testing of the tax loss hypothesis.

In this chapter, we discuss the hypothesis proposed in this thesis and the regression models designed to test the hypothesis. The remainder of this chapter is structured as follows. In section 4.1, we cover the general hypothesis and the regression models, while in sections 4.2 through 4.4, we discuss hypothesis tested in the specific empirical chapters. Finally, section 4.5 provides a brief summary of the chapter.

4.1. General Hypothesis

There are two hypothesis, which will be tested for each of the seasonality patterns.

Hypothesis 1: Seasonality patterns in the FX market are different from those in the equity market due to different structures of the equity and currency markets.

Hypothesis 2: Seasonality patterns are more pronounced in the post euro period, due to currency markets becoming more volatile and more recent period being characterized by the economic slowdown.

Since the vast majority of the papers on the seasonality patterns focused on the equity market, it would be interesting to see how FX anomalies and patterns are different from those in the equity market. *Hypothesis 1* will be tested by comparing the results of this study to the findings of the papers on the stock market anomalies. Biais (1993) and Perraudin and Vitale (1995) already showed how the difference between the structures of the equity and currency markets could lead to the significant differences in the market characteristics, such as seasonality patterns. From one side, one can argue that since the FX market is the most liquid and the largest financial market in the world, it is the most efficient and is less likely to display seasonality patterns, compared to the equity market. From another side, FX market does not have definite closures since it is organized around partially overlapping trading sessions in the regional centres worldwide, which implies that the news announcements tend to impact FX rates immediately. If the news announcements significantly contribute to the anomalies, such as day of the week effect, currency markets are likely to display stronger patterns than the stock market, which have specific trading hours, outside which, the impact of the news announcement is limited. Besides, the introduction of euro made currency markets more volatile (Heaney and Swieringa, 2003), resulting in more pronounced seasonality patterns in the FX market, but did not have any significant impact on the equity market anomalies.

Finally, we break a sample period of 1994-2003 into two five-year sub samples, in order to test *hypothesis 2*, which suggests that the seasonality patterns, such as the day of the week effect is more pronounced in the post euro sub sample of 1999-2003. As predicted by Masson and Turtelboom (1997), Benassy-Quere et. al (1997), Obstfeld (1998) and Eichengreen (2000), and shown by Heaney and Swieringa (2003), the currency markets volatility increased after the introduction of Euro. Increased volatility at the FX market should make exchange rate movements more volatile, resulting in more pronounced seasonality patterns. Another argument for having more pronounced seasonality patterns in the post euro period is the fact that the market direction explains the seasonality patterns in the asset return series[2]. If this is true, then the FX spot market should become more sensitive to the return anomalies in a declining rather than a rising market. Since US dollar appreciated through the entire period of 1990s and depreciated in the end of 1990s and the first half of this decade, one should expect FX markets to display more pronounced patterns in 1999-2003 sub sample, compared to 1994-1999, which is consistent with the hypothesis 2. The hypothesis 2 would be rejected if the seasonality patterns are found to be more pronounced in the first 5 year sample period, which could be explained by the findings that the financial markets have become more efficient recently, resulting in the fading calendar patterns (Gay and Kim, 1987, Chang, 1988, Johnston et. al, 1991).

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[2] According to Fishe et. al (1993) and Arsad and Coutts (1997), the day of the week effect in the equity markets is much less visible during periods of stock market rises. Similar to Fishe et. al (1993) and Arsad and Coutts (1997), Steeley (2001) provided the evidence that the weekend effect had disappeared in the UK stock market in 1990s, but found evidence of the significant seasonality patterns when negative returns only are considered.

4.2. Announcement Effect

We investigate whether our sixteen scheduled macro news announcements, the FOMC minutes, interest rate announcements and BOJ interventions have significant impact on the FX volatility prior to, on and after the announcement day, respectively. We discuss the hypothesis relating to the impact of scheduled and unscheduled news announcements in section 4.2.1, those relating to the impact of central bank interventions in section 4.2.2 and those relating to the impact of unexpected news in section 4.2.3.

4.2.1. Impact of Scheduled and Unscheduled News on the FX Volatility

Hypothesis 3: There exists an announcement effect, indicated by the statistically significant implied volatility changes on the news announcement days.

Hypothesis 4: Implied volatility tends to increase prior to the news announcements and fall following the announcements.

The following regression is used to study the impact of the news announcements on FX volatility:

$$V_{i,t} = \alpha_0 + \alpha_i A_{i,k,t} + \sum_{t=0}^{5} \beta_i A_{i,k,t-5\ldots t-1} + \sum_{t=0}^{5} \gamma_i A_{i,k,t+1\ldots t+5} + \varepsilon_{it} \qquad (4\text{-}1)$$

where,

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$A_{i,k,t}$ is the dummy variable that takes value of one if the macroeconomic announcement k takes place in a period t, and zero otherwise;

$A_{i,k,t-5\ldots t-1}$ is the series of five dummy variable that takes value of one on each of five days preceding the macroeconomic announcement k and zero otherwise;

$A_{i,k,t+1...t+5}$ is the series of five dummy variable that takes value of one on each of five days following the macroeconomic announcement k and zero otherwise;
ε_{it} is the error term.

The regression coefficients α_i should be significantly different from zero in order for the news releases to have a significant impact on the FX volatility, which is consistent with the *hypothesis 3*. Other regression coefficients β_i and γ_i indicate the difference between average volatility and volatility during five periods prior to and five periods after period *t*, respectively. We expect to find statistically significant negative β_i and positive α_i and γ_i coefficients that would indicate that *hypothesis 4* is true. This is expected, because prior to the news announcements, uncertainty, measured by the implied volatility tends to increase, while, following the announcements, it tends to fall, as the source of the uncertainty is eliminated. Additional variables are introduced in order to see how FX volatility behaves before and after the announcements.

The first null hypothesis to be tested is that coefficients α_i is not significantly different from zero, while the alternative hypothesis (*hypothesis 3*) is that the news announcements significantly impact FX volatility. The regression coefficients obtained for the individual macro announcements will help to identify whether different types of the announcements impact the exchange rate volatility differently. The rejection of the null hypothesis that β_i and γ_i coefficients are not significantly different from zero in favor of the *hypothesis 4* would suggest that the news announcements have significant impact on the FX volatility prior to and after the announcement day, respectively.

4.2.2. Impact of Central Bank Interventions on the FX Volatility

Hypothesis 5: The impact of central bank interventions on the FX implied volatility is dependent not only on the presence of the central bank in the FX market, but also on the magnitude of the intervention.

$$V_{i,t} = \alpha_0 + \sum \alpha_1 M_t + \varepsilon_{it} \quad (4\text{-}2)$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;

M_t denotes the relative change in the amount spent by BOJ on the intervention as a proportion of the money supply on day t;

E_{it} is the error term.

The regression coefficient α_1 should be significantly different from zero for the FX volatility to be dependant on the magnitude of the BOJ interventions, which is consistent with the *hypothesis 5*. The regression coefficient will also be compared to the regression coefficients for the dummy variables denoting the days of the BOJ interventions to understand whether the impact of the intervention of the currency market volatility is driven by the magnitude of the intervention or the mere presence of the central bank at the market. The acceptance of the null hypothesis (that the coefficient α_1 is not significantly different from zero) would suggest that the FX volatility is affected by the mere occurrence of the intervention, not its magnitude. Although Frenkel et. al (2003) suggested that the presence of the BOJ in the market, not the magnitude of its interventions impacts FX volatility, we hypothesize that the FX implied volatility impact should be more significant for the intervention, where larger amounts are involved. Unlike Frenkel et. al (2003), we use the relative values of the central bank interventions by incorporating money supply into the regression to account for the fact that the money supply could have an impact on the relation between FX implied volatility and the magnitude of a central bank intervention.

4.2.3. Impact of Unexpected News on the FX Volatility

Hypothesis 6: The impact of unexpected news on the FX implied volatility is different from the impact of the expected news.

Hypothesis 7: The impact of news with large surprise/unexpected element on the FX implied volatility is different from the impact of news with small surprise element.

Hypothesis 8: The impact of good news on the FX implied volatility is different from the impact of bad news.

Three different regressions are run for each of the scheduled macro announcements to avoid the problem of multicollinearity among the independent variables. The first regression tries to capture an impact of the "surprise" (unexpected) component of the news announcement on the FX volatility, while the other two regressions are run to identify whether this impact is caused by large or small and positive or negative news.

The following regression will be run to study the effect of the surprise announcements on the exchange rate volatility[3]:

$$\mathbf{V}_{i,t} = \alpha_0 + (1)\sum \alpha_i\, \mathbf{S}_{i,k,t} + (2)\sum \beta_i\, \mathbf{S(l)}_{i,k,t} + (2)\sum \gamma_i\, \mathbf{S(s)}_{i,k,t} + (3)\sum \delta_i\, \mathbf{S(p)}_{i,k,t} + (3)\sum \eta_i\, \mathbf{S(n)}_{i,k,t} + \varepsilon_{it} \qquad \mathbf{(4\text{-}3)}$$

where,

[3] numbers 1, 2 and 3 preceding independent variables indicate the variables used in each of three regressions

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$S_{i,k,,t}$ is the surprise component of the macro announcement k on day t, and is equal to ln (A/E) or A-E[4], where A is the realized value while E is the expected[5] value;

$S(l)_{ik,,t}$ is the surprise component of the macro announcement k with the large surprise element (more than one standard deviation from the mean) on day t;

$S(s)_{ik,,t}$ is the surprise component of the macro announcement k with the small surprise element (less than one standard deviation from the mean) on day t;

$S(p)_{ik,,t}$ is the surprise component of the macro announcement k with the positive surprise element (where realized value A is greater than expected value E) on day t;

$S(n)_{ik,,t}$ is the surprise component of the macro announcement k with the negative surprise element (where realized value A is less than expected value E) on day t;

ε_{it} is the error term.

The regression coefficients α_i should be significantly different from zero in order for the surprise element of the scheduled macro announcements to have a significant impact on the FX volatility, providing an evidence in support of the *hypothesis 6*. The coefficients β_i and γ_i, indicate the implied volatility impact of the announcements with large[6] and small[7] surprise elements. Finally, the regression coefficients δ_i and η_i, indicate the volatility impact of the news with positive and negative surprise elements[8], respectively. The sign of the coefficient would be negative, if the announced results were in line with the expected ones, indicating the

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[4] ln (A/E) is estimated for most indicators, while A-E is estimated only when the use of ln(A/E) would be misleading (e.g. when both realized and expected figures are negative and the realized figure is smaller than expected, ln (A/E) would be positive)

[5] Consensus number obtained from the finance section of a www.yahoo.com

[6] more than one standard deviation from the mean

[7] less than one standard deviation from the mean

[8] Positive surprises of Retail Sales, Durable Goods, Construction Spending, GDP, Auto Sales, Consumer Confidence, Industrial Production, Leading Indicators and Housing Starts as well as negative surprises of Trade Balance, Unemployment, CPI, PPI, Current Account and Non Farm Payrolls are considered as favorable news

elimination of the source of uncertainty leading to the fall in the implied volatility. The sign would be positive, if the actual results were different from the expected ones, leading to the increased market uncertainty and therefore increased implied volatility. We are interested in the significance of the regression coefficients and therefore in the magnitude of the impact of news with small vs. large surprise elements and those of good vs. bad news on the FX implied volatility, rather than in the sign of the regression coefficients.

The first null hypothesis to be tested is that coefficient α_i is not significantly different from zero, while the alternative hypothesis is that the unexpected component of the news announcements significantly affects FX implied volatility (*hypothesis 6*). Consistent with the existing literature (Andersen et. al, 2003), it would be logical to hypothesize that unexpected news should impact implied volatility stronger than expected news. The second null hypothesis is that β_i and γ_i coefficients are not significantly different from zero, indicating that the impact of the surprise announcements (if any) on the currency volatility does not depend on the magnitude of these surprises. The rejection of this hypothesis in favour of the alternative *hypothesis 7* would suggest that the impact of the surprise announcements on the FX volatility is driven by large (small) surprises. Finally, the third null hypothesis to be tested is that δ_i and η_i coefficients are not significantly different from zero, indicating that the impact of the surprise announcements (if any) on the currency volatility does not depend on the sign of these surprises. The rejection of this null hypothesis in favour of the alternative *hypothesis 8* would suggest that the impact of the surprise announcements on the FX volatility is driven by positive (negative) surprises. The *hypothesis 8* will be tested to study a sign effect, a phenomenon documented in the literature, which implies that bad news have stronger impact on the financial asset volatility than good news. Based on the existing literature on the sign effect (Andersen et. al, 2003 and Chan et. al, 2003), we expect bad news to have stronger impact on the FX implied volatility than good news.

Given that the timing of the scheduled news is known in advance, we expect to find an evidence of the increased implied volatility prior to the scheduled news announcement as market uncertainty tends to increase prior to the news releases. We also expect to find an evidence of the reduced implied volatility on the announcement day as the source of the uncertainty disappears. However, we recognize that the content of the news release is also important, given that the announcements with the material surprise element (difference between actual results and consensus estimates) could drive implied volatility up. We therefore test the hypothesis 6 to understand whether the news with the material surprise element have a significant impact on the implied volatility and therefore whether there is a material difference between the impact of the expected and unexpected news on the implied volatility.

We also try to understand whether the announcement effect is asymmetric by differentiating between large vs. small and positive vs. negative surprise element (good or bad news). From one side, large surprises should have a more significant impact, given that the news with the large surprise element drive volatility up more than the news with the small surprises. From another side, traders avoid trading when big news are announced and when the large market participants (eg central banks) are actively involved. If this true, small surprises could have a more significant impact that large surprises. We hypothesize that bad news should become more important in the good times when economy is doing well, while positive news should have more significant impact on the FX implied volatility during recession. Given that apart from 2001-2003 period, our sample coincides with the years of a significant US and global GDP growth, we expect to find an evidence of a more significant impact of bad news.

We are interested in the magnitude, rather than the sign of the coefficients. The sign of the coefficient would indicate whether particular announcement is in line with the expected results, but would not explain the impact of good or bad (large or small) news. This is in line with the announcement effect (see Andersen and Bollerslev, 1998), according to which, implied volatility tends to increase prior to the news announcements, which indicate increased uncertainty. As news are released and assuming that the announced result is not very different from the expected one, the source of the uncertainty disappears, and implied volatility falls again. However, if the announced results are different from the expected ones, implied volatility tends to increase reflecting the increased uncertainty. The purpose of the regression model 4-3 is to capture the impact of large versus small (good versus bad) unexpected news on the FX implied volatility, rather than to examine the direction of the implied volatility movements following the news announcement.

4.3. Seasonality Patterns in the FX Returns and Implied Volatilities

In this section, we summarize hypothesis and regression models proposed and designed to identify seasonality patterns in the FX returns and implied volatilities. We discuss the day of the week effect in section 4.3.1. Monthly and intra-monthly patterns are examined in sections 4.3.2 and 4.3.3, respectively. Turn of the year effect is discussed in section 4.3.4, while holiday effect is examined in section 4.3.5. Finally, section 4.3.6 focuses on the quarterly patterns.

4.3.1. Day of the Week Effect

Hypothesis 9: There exists a day of the week effect, indicated by the statistically significant difference between FX returns and implied volatilities on different days of the week.

Hypothesis 10: Day of the week effect is more pronounced on the announcement, rather than non-announcement days.

The following regression models are designed to study the intraweek patterns in the FX return series and implied volatilities. The dummy variable for Monday (in the case of the FX returns) and Wednesday (in the case of the FX implied volatilities) is excluded to avoid the dummy variable trap.

$$R_{i,t} = \alpha_0 + \sum\beta_i T_{i,t} + \sum\delta_i W_{i,t} + \sum\gamma_i Th_{i,t} + \sum\eta_i Fi,t + \varepsilon_{it} \qquad \textbf{(4-4)}$$

$$V_{i,t} = \alpha_0 + \sum\alpha_i V_{i,t-1} + \sum\beta(v)_I M_{i,t} + \sum\gamma(v)_i T_{i,t} + \sum\delta(v)_I Th_{i,t} + \sum\eta(v)_i Fi,t + \sum\theta(v)_i S_{i,t} + \sum\lambda(v)_i Sun_{i,t} + \varepsilon_{it} \qquad \textbf{(4-5)}$$

$$R_{i,t} = \alpha_0 + \sum\gamma_{ia} T_{i,t} D(a)_i + \sum\gamma_{in} T_{i,t} D(n)_i + \sum\beta_{ia} W_{i,t} D(a)_i + \sum\beta_{in} W_{i,t} D(n)_I + \sum\delta_{ia} Th_{i,t} D(a)_i + \sum\delta_{in} Th_{i,t} D(n)_i + \sum\eta_{ia} Fi,t\, D(a)_i + \sum\eta_{in} Fi,t\, D(n)_i + \varepsilon_{it} \qquad \textbf{(4-6)}$$

$$V_{i,t} = \alpha_0 + \sum\alpha_i V_{i,t-1} + \sum\beta(v)_{ia} M_{i,t} D(a)_i + \sum\beta(v)_{in} M_{i,t} D(n)_i + \sum\gamma(v)_{ia} T_{i,t} D(a)_I +$$

$$\sum\gamma(v)_{in} T_{i,t} D(n)_i + \sum\delta(v)_{ia} Th_{i,t} D(a)_i + \sum\delta(v)_{in} Th_{i,t} D(n)_i + \sum\eta(v)_{ia} F_{i,t} D(a)_i + \sum\eta(v)_{in} F_{i,t} D(n)_i + \sum\theta(v)_i S_{i,t} + \sum\lambda(v)_I Sun_{i,t} + \varepsilon_{it} \quad \textbf{(4-7)}$$

where,

$R_{i,t}$ is logarithmic change in the FX rate *i* on day *t*, equal to ln (P_t/P_{t-1}), where P_t denotes the close exchange rate *i* on day *t*, while P_{t-1} denotes the close exchange rate *i* on day *t-1*;

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln; (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;

$M_{i,t}$ is a dummy variable that is equal to one when day t is Monday and zero otherwise;

$T_{i,t}$ is a dummy variable that is equal to one when day t is Tuesday and zero otherwise;

$W_{i,t}$ is a dummy variable that is equal to one when day t is Wednesday and zero otherwise;

$Th_{i,t}$ is a dummy variable that is equal to one when day t is Thursday and zero otherwise;

$F_{i,t}$ is a dummy variable that is equal to one when day t is Friday and zero otherwise;

$S_{i,t}$ is a dummy variable that is equal to one when day t is Saturday and zero otherwise;

$Sun_{i,t}$ is a dummy variable that is equal to one when day t is Sunday and zero otherwise;

D(a) is a dummy variable that is equal to one when at least one announcement is made that day and zero otherwise;

D(n) is a dummy variable that is equal to one when no announcement is made that day and zero otherwise;

ε_{it} is the error term.

The values of the regression coefficients should be significantly different from zero (*hypothesis 9*), for the significant difference to exist between FX return series (implied volatilities) on Monday (Wednesday) and the remaining days of the week. The sign of the coefficient is also important, since significantly positive coefficient would indicate that price (implied volatility) change on that particular day of the week is significantly higher than Monday (Wednesday) return (implied volatility change), while negative coefficient would indicate that the price (implied volatility) change on that particular day is significantly lower than Monday (Wednesday) return (implied volatility change). Given structural differences between FX and stock markets, we expect currency markets to display intraweek and intraday seasonality patterns different from those observed in the stock market. For example, the fact that FX is 24-hour market suggests that there is less opportunity for informed trader to take advantage of the private information. This implies that the private information hypothesis (will be discussed later), which explains negative Monday returns in the stock market, is not so relevant for the currency market.

The regression models 4-6 and 4-7 are designed to test whether there is a link between the day of the week effect and the release of the scheduled announcements. The model is used to test the hypothesis that FX intraweek anomalies are driven by the news announcements. For the implied volatilities, the results will also help to test the hypothesis proposed by Ederington and Lee (1996), according to which the uncertainty, measured by the implied volatility, would be high prior to the release of the scheduled announcements and would fall following the release, as the source of uncertainty is resolved.

The null hypothesis would be rejected in favour of the *hypothesis 10*, if the daily returns (implied volatility changes) on the announcement days are found to be more statistically significant than returns (implied volatility changes) on non-announcement days. For the implied volatilities, we expect implied volatility to fall on non-announcements days and rise on the announcement days. Since Thursday and Friday are the days associated with the large amount of the US macroeconomic indicator releases, it is reasonable to expect δ_{ia}, η_{ia},. $\delta(v)_{ia}$ and $\eta(v)_{ia}$ coefficients to be statistically significant and $\delta(v)_{ia}$ and $\eta(v)_{ia}$ coefficients to be negative, if the *hypothesis 10* is true. A list of the sixteen scheduled announcements used in this empirical study is provided in Table 5-8. The use of the sixteen scheduled announcements implies that the results are subject to the assumption that the sixteen indicators capture all the announcement effect. As another robustness test, we examine whether the presence of the announcements as a whole alters the day of the week effects or the lack of such (which is the contribution to the existing literature[9]).

4.3.2 Monthly Patterns

Hypothesis 11: Average daily rate of return in January is negative and is significantly different from zero.

Hypothesis 12: There exists a January effect indicated by the January returns being significantly different from the returns generated during the rest of the year.

The following regression model is used to study the monthly patterns in the FX return series.

$$R_{i,t} = \alpha_0 + \sum \beta_i J_{i,t} + \varepsilon_{it} \qquad \textbf{(4-8)}$$

$$R_{i,t} = \alpha_0 + \sum \alpha_i M_{i,t} + \varepsilon_{it} \qquad \textbf{(4-9)}$$

where,

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (P_t/P_{t-1}), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;

[9] In spite of trying to explain FX day of the week effect by the US news announcements, Yamori and Kurihara (2004) did not test this relation.

$J_{i,t}$ is a dummy variable that is equal to one when day t is in January and zero otherwise;

$M_{i,t}$ is a dummy variable that takes value of one when day t is in a month from February to December and zero otherwise;

ε_{it} is the error term.

The coefficients (β_i) attached to $J_{i,t}$ dummy variable show by how much the average January return on the exchange rate *i* that receives a dummy value of 1 differ from that of the benchmark indicating other months' returns. The null hypothesis would be rejected in favour of the *hypothesis 12*, if the coefficients are significantly different from zero. We expect to find a negative and statistically significant β_i coefficients, which would indicate that the January returns are negative and significantly lower than returns generated during the remaining months of the year and would be consistent with the *hypothesis 11 and 12*. Negative and statistically significant β_i coefficients[10] would indicate that the positive and statistically significant January returns documented in the stock markets (Roll, 1983, Jaffe and Westerfield, 1989, and Agrawal and Tandon, 1994) also occur in the currency markets. We hypothesize that if the January effect in the equity markets is indeed caused by the tax loss-selling hypothesis, which is by far the most popular explanation provided in the existing literature on the January effect (Roll, 1983, Tinic and Barone-Adesi, 1983, Keim, 1989), USD should also appreciate in January causing January effect in the FX market. According to the tax loss-selling hypothesis, investors sell poorly performing stocks prior to the tax year-end to realize their losses against their taxable income. After the end of the tax-year, price pressure disappears and the prices reach equilibrium level. If this true, we would expect to see USD depreciation prior to the tax year-end and USD appreciation in January.

Finally, the results of the regression model 4-9 will help to identify months, which generate statistically significant returns. The dummy variable for January is excluded to av recognize that even if January returns turn out to be negative and statistically

[10] Exchange rates are the prices of the foreign currencies in USD, so negative coefficients indicate positive USD returns.

significant, while December returns turn out to be positive and significant, the results could still be explained by the factors other than tax loss selling[11]. Since in the UK, the tax year-end for investors is April 5, we hypothesize that the final confirmation of the FX January effect (if any) being explained by the tax loss selling would be negative and statistically significant USD/GBP April returns.

We also test *hypothesis* 2, according to which, January effect should be more pronounced in the post euro period. Gu (2003) suggested that the January effect is weaker during the periods of higher real GDP growth and stronger during periods of lower GDP growth. Besides, the anomaly is more apparent for the years with the lower inflation and the contribution of the January return to the year's return is relatively more significant for "poor" market years than for "good" market years. Since the period of 1994-1999 is associated with the economic growth in the US, while the interval of 1999-2004 is considered as the period of the economic slowdown, we hypothesize that the monthly seasonality patterns, including the January effect is stronger in the sample period of 1999-2003, compared to 1994-1999.

As indicated by Gu (2003), the regression analysis cannot reveal the dynamics of the January effect over time. We, therefore, use a power ratio method introduced by Gu (2003) to measure the contribution of the January return to the return of the year.

R_j = (1+January Return)^12, where power 12 is used because there are 12 months in the year;

R_y = (1+Return on the year);

R_j/R_y -power ratio since R_j is a factor of power.

Obviously, R_j and R_y are always greater than zero. When R_j/R_y is equal to one, then the January return is as good as the average of other months of the year. When R_j/R_y is greater than one, then the January return is better than the average of

[11] As pointed out by Hillier and Marshall (2002), the tax year coincides with the calendar year in most countries, including US, and therefore, most tests are joint tests of the two year-ends.

other months of the year, and when R_j/R_y is less than one, then the January return is below the average of other months of the year. Since, the exchange rates used in our study are the prices of the foreign currencies in the USD, we expect to see the power ratios below one in most years to prove that the January effect is persistent over time.

4.3.3. Intra-Monthly Patterns

Hypothesis 13: There is a significant first half of the month effect indicated by the average return (implied volatility) during the first half of any month being statistically different from the average return during the second half.

Hypothesis 14: There is a significant turn of the month effect indicated by the average return (implied volatility) around turn of the month being statistically different from the average return (implied volatility) during the remaining days of a month.

The following regression model is used to study intra-monthly patterns in the FX return series and implied volatilities.

$$R_{i,t} = \alpha_0 + \sum \beta_{i(fh)} FH_{i,t} + \sum \beta_{i(s)} S_{i,t} + \sum \beta_{i(end)} END_{i,t} + \varepsilon_{it} \quad \textbf{(4-10)}$$

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta(v)_{i(fh)} FH_{i,t} + \sum \beta(v)_{i(tom)} TOM_{i,t} + \varepsilon_{it} \quad \textbf{(4-11)}$$

where,

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (P_t/P_{t-1}), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day t-1;

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day t-1;

$FH_{i,t}$ is a dummy variable that is equal to one when day t is in the first half of the month, and zero otherwise;

$S_{i,t}$ is a dummy variable that is equal to one when day t is one of the first 3 days of the month, and zero otherwise;

$END_{i,t}$ is a dummy variable that is equal to one when day t is one of the last 3 days of the month, and zero otherwise;

$TOM_{i,t}$ is a dummy variable that is equal to one when day t is in the last and first 5[12] days of the month, and zero otherwise;

ε_{it} is the error term.

The coefficient $\beta_{i(fh)}$ ($\beta(v)_{i(fh)}$) attached to $FH_{i,t}$ dummy variable show by how much average daily return (implied volatility change) on the exchange rate *i* during the first half of a month that receives a dummy value of 1 differs from that of the benchmark indicating average daily return (implied volatility change) over the second half. The coefficients $\beta_{i(fh)}$ and $\beta_{i(s)}$ attached to $S_{i,t}$ and $END_{i,t}$ dummy variables show by how much return on the exchange rate *i* during the first and last three day of a month that receives a dummy value of 1 differ from that of the benchmark indicating return over the remaining days of a month. Finally, the coefficient $\beta(v)_{i(tom)}$ attached to $TOM_{i,t}$ dummy variable show by how much implied volatility change on the exchange rate *i* during the first and last five day of a month that receives a dummy value of 1 differ from that of the benchmark indicating average daily implied volatility change over the remaining days of a month. The null hypothesis would be rejected in favour of the *hypothesis 13* and *14*, if the coefficients are significantly different from zero. In other words, the values of the regression coefficients $\beta_{i(fh)}$, $\beta_{i(s)}$, $\beta_{i(end)}$, ($\beta(v)_{i(fh)}$ and $\beta(v)_{i(tom)}$ should be significantly different from zero, for the significant difference to exist between average currency returns (implied volatility changes) during the first half of the month/ turn of the month and average returns (implied volatility changes) during the remaining days of a month.

[12] we define turn of a month as the first and last 5 (as opposed to 3) days of a month in order to make it easy to compare our findings with those of Martikainen et. al (1995)

We hypothesize that if the average return in the stock market during the first half a month exceeds average return during the second half (Ariel, 1987), then the demand for stocks should be higher in the first half of a month. Possible explanations for the equity intra-monthly patterns are dividend effect, tax loss selling and news announcements concentrated in one part of the month. We hypothesize that the seasonality in the equity markets should drive calendar patterns in the FX markets. For example, a tax loss selling is likely to create capital flows and therefore result in the FX seasonality. Because of the capital flows, higher demand for stock imply higher demand for USD, and therefore lower foreign currency returns in terms of USD in the first half of a month, compared to the second half. Consistent with the existing literature on the FX (Aydogan and Booth, 1999) and equities (Penman, 1987 and Stewart, 1987), we expect to find evidence of the positive return generated in the beginning of a month and negative return generated in the final days of a month. Given that substantial payments in the US economy (e.g. salaries and debt interest) are made in the end of a month, we expect to find an evidence of a statistically significant difference between implied volatility changes around a turn of a month and during the remainder of a month (consistent with Martikainen et. al, 1995).

4.3.4. Turn of the Year Effect

Hypothesis 15: There exists a turn of the year effect indicated by the currency returns and implied volatility changes around the turn of the year being statistically different from the FX returns and implied volatility changes during the remaining days of a year.

Hypothesis 16: The market participants' anticipation of the increase in the return and volatility is reflected in the implied volatility rising prior to the turn of the year and falling around the turn of the year, when variance is expected to be abnormally high.

$$R_{i,t} = \alpha_0 + \sum \beta_i \, TOY_{i,t} + \varepsilon_{it} \qquad \textbf{(4-12)}$$

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_{i(-60)} D(-60)_{i,t} + \sum \beta_{i(-30)} D(-30)_{i,t} + \sum \beta_{i(-10)} D(-10)_{i,t} + \sum \beta_{i(-2)} D(-2)_{i,t} + \sum \beta_{i(+2)} D(+2)_{i,t} + \sum \beta_{i(+10)} D(+10)_{i,t} + \varepsilon_{it} \quad \textbf{(4-13)}$$

where,

$R_{i,t}$ is logarithmic change in the FX rate *i* on day *t*, equal to ln (P_t/P_{t-1}), where P_t denotes the close exchange rate *i* on day *t*, while P_{t-1} denotes the close exchange rate *i* on day *t-1*;

$TOY_{i,t}$ is a dummy variable that is equal to one when day t is in the first or last three business days of the year and 0 otherwise;

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;

$D(-60)_{i,t}$ is a dummy variable that is equal to one when day t is between trading day -60 and trading day -30, where trading day -60 is the day 60 days prior to the year end, and zero otherwise;

$D(-30)_{i,t}$ is a dummy variable that is equal to one when day t is between trading day -30 and trading day -10, and zero otherwise;

$D(-10)_{i,t}$ is a dummy variable that is equal to one when day t is between trading day -10 and trading day -2, and zero otherwise;

$D(-2)_{i,t}$ is a dummy variable that is equal to one when day t is between trading day -2 and trading day +2, and zero otherwise;

$D(+2)_{i,t}$ is a dummy variable that is equal to one when day t is between trading day +2 and trading day +10, and zero otherwise;

$D(+10)_{i,t}$ is a dummy variable that is equal to one when day t is between trading day +10 and trading day +30, and zero otherwise;

ε_{it} is the error term.

The null hypothesis for the regression model 4-12 would be rejected in favour of the *hypothesis 15*, if the coefficient β_i, which shows by how much return (implied volatility change) on the exchange rate i during the last and first three business days of a year differ from the average return (implied volatility change) during the remainder of a year, is statistically significant. The coefficients should be statistically significant for the turn of the year effect to exist in the FX returns (implied volatilities).

The null hypothesis for the regression model 4-13 would be rejected in favour of the *hypothesis 16*, if the coefficients $\beta_{i(-10)}$, $\beta_{i(-2)}$, $\beta_{i(+2)}$, and $\beta_{i(+10)}$ are significantly different from zero. In other words, the values of the regression coefficients should be significantly different from zero, for the significant difference to exist between average FX return (implied volatility) during the turn of the year (first and last 10 days) and return (implied volatility) during the remaining days of any year.

The null hypothesis that $\beta_{i(-60)}$, $\beta_{i(-30)}$, $\beta_{i(-10)}$, $\beta_{i(-2)}$, $\beta_{i(+2)}$, and $\beta_{i(+10)}$ coefficients are not significantly different from zero would be rejected in favour of the *hypothesis 16*, if the coefficients $\beta_{i(-60)}$, $\beta_{i(-30)}$ and possibly $\beta_{i(-10)}$ are positive and significantly different from zero. The coefficients $\beta_{i(-2)}$, $\beta_{i(+2)}$, $\beta_{i(+10)}$ and possibly $\beta_{i(-10)}$ should not be positive and significantly different from zero for the *hypothesis 16* to be valid.

We hypothesise that if the turn of the year effect does exist in the stock markets, as indicated by Keim (1983), Roll (1983), and Lakonishok and Smidt (1984) for the return series and Rogalski and Maloney (1989) and Barone – Adesi and Cyr (1994) for the implied volatilities, currency returns and implied volatilities around the turn of the year should also be significantly different from those observed during the remaining days of a year. Since the turn of the year effect is closely related to the January effect, as pointed out by Roll (1983), Tinic and Barone-Adesi (1983), Reinganum (1983), and Keim (1989), both anomalies are likely to be caused by the tax loss-selling hypothesis. According to the tax loss-selling hypothesis, investors sell poorly performing stocks prior to the tax year-end to realize their losses against their taxable income. After the end of the tax-year, price pressure disappears and the prices reach equilibrium level. If this true, we would expect to see USD depreciation in the end of December prior to the tax year-end, which is also the calendar year end, and USD appreciation in the beginning of January.

We contribute to the existing literature on the turn of the year effect by focusing on the FX rather than stock market. We develop the *hypothesis 13* to test Rogalski and Maloney's (1989) theory that increasing implied volatilities prior to the end of the year reflect the market's anticipation of the turn of the year effect. This hypothesis has been tested by for the equity-implied volatilities, but has never been studied in the currency markets. In order to test Rogalski and Maloney's (1989) hypothesis for the return series, as one of the robustness tests, we run another regression by defining turn of the year as the last and first 10 days of a year. This will allow us to test that the market anticipates the turn of the year effect in advance. Finally, again for the return series, we run another regression, where we use two separate dummy variables for the last three days in December and the first three days in January. We expect to find positive December and negative January coefficients, as evidence of a tax loss-selling hypothesis.

4.3.5. Holiday Effect

Hypothesis 17: There is a significant holiday effect, indicated by the average daily return and implied volatility during the day preceding and following official US and non-US holidays being statistically different from the average daily return and implied volatility during the remaining days of a year.

$$R_{i,t} = \alpha_0 + \sum \beta_{i(h-)} H_{-,t} + \sum \beta_{i(h+)} H_{+i,t} + \varepsilon_{it} \qquad \textbf{(4-14)}$$

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta(v)_{i(h-)} H_{-i,t} + \sum \beta(v)_{i(h+)} H_{+I,t} + \varepsilon_{it} \qquad \textbf{(4-15)}$$

where,

$R_{i,t}$ is logarithmic change in the FX rate *i* on day *t*, equal to ln (P_t/P_{t-1}), where P_t denotes the close exchange rate *i* on day *t*, while P_{t-1} denotes the close exchange rate *i* on day *t-1*;

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;

$H-_{i,t}$ is a dummy variable that is equal to one when day t precedes the official holiday in US/UK/Switzerland/Japan/Germany, and zero otherwise;

$H+_{i,t}$ is a dummy variable that is equal to one when day t follows the official holiday in US/UK/Switzerland/Japan/Germany, and zero otherwise;

ε_{it} is the error term.

The null hypothesis would be rejected in favour of the *hypothesis 17*, if the coefficients $\beta_{i(h-)}$, $\beta_{i(h+)}$, $\beta(v)_{i(h-)}$ and $\beta(v)_{i(h+)}$ are significantly different from zero. In other words, the values of the regression coefficients should be significantly different from zero, for the significant difference to exist between average daily return and implied volatility during the day preceding and following the official holidays and the remaining days of a year. The list of the official holidays used in this study is provided in Table 3-10.

We expect to find positive pre holiday and negative post holiday return coefficients, because of the several reasons. First, since the international transactions tend to be denominated and invoiced in the exporting firm's currency (Grassman, 1973), firms in every country will likely be net buyers of foreign currency and net sellers of the home currency. If the domestic firms are indeed net buyers of foreign currency (shown by Cornet et. al, 1995), domestic banks would provide liquidity to the market, by taking the opposite side of these transactions and therefore accumulate net long positions in the domestic currency. In US, US banks would have natural long USD positions, which they would flatten by selling USD inventories just prior to the official holidays, in order not be exposed to the holiday (when markets are closed). This would cause USD depreciation prior to the holiday and USD appreciation after the holiday, as the same banks would buy USD back after the markets open following the holiday. Another reason for expecting positive pre holiday and negative post holiday coefficients is that as US residents convert USD into foreign currencies prior to US holidays for the purpose of travel or shopping, USD depreciates. The necessity to convert money back to USD after the holidays results in USD appreciation following the holiday.

For the FX implied volatilities, since the market activity over holidays resembles the market behavior prior to and during the weekends, we expect implied volatilities' behavior around holidays to similar to that around weekends. Consistent with the private information theories of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), which explain a fall in implied volatility prior to weekends and an increase following a weekend, we expect to find a negative pre holiday and positive post holiday implied volatility coefficients.

The examination of the holiday effect in the currency markets with reference to both US and non-US holidays provides an opportunity to distinguish between anomalous patterns originating in the US and those originating in other countries, which is one of the contributions of this study to the existing literature[13] on the holiday effect in the currency markets. If anomalies are being driven by the US holidays, we should expect to observe abnormal returns and implied volatilities on days before and after US holidays. If, on the other hand, currency calendar seasonalities are driven by non-US holidays, we should expect to see statistically significant returns and implied volatilities on days before and after non-US holidays. Besides, none of the existing papers on the FX calendar effects studied the behavior of the FX prices on post holiday days, and therefore the inclusion of the dummy variable that captures post holiday return provides an opportunity to contribute to the existing literature.

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[13] Cadsby and Ratner (1992) studied the impact of US and non US holidays for the equities

4.3.6. Turn of the Quarter Effect

Hypothesis 18: There is a significant turn of the quarter effect, indicated by the implied volatility during the first two weeks in calendar quarters two through four being statistically different from the volatility during the remaining days of any year.

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_{i(q)} Q_{i,t} + \varepsilon_{it} \qquad \textbf{(4-16)}$$

where,

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$Q_{i,t}$ is a dummy variable that is equal to one when day t is in the first two weeks of April, July and October, and zero otherwise;

ε_{it} is the error term.

The null hypothesis would be rejected in favour of the *hypothesis 18*, if the coefficient $\beta_{i(q)}$ is significantly different from zero. In other words, the values of the regression coefficients should be significantly different from zero, for the significant difference to exist between implied volatilities during the first two weeks of April, July, and October and the remaining days of the year. The hypothesis 15 is developed to test Barone – Adesi and Cyr (1994)'s findings on the quarterly effect in the equity implied volatilities for the FX market[14].

14 Barone – Adesi and Cyr (1994) did not find any evidence of a quarterly effect in the implied volatilities of the S&P 500 futures options.

4.4. Relation Between FX Returns and Implied Volatilities

In this section, we summarize hypothesis and regression models designed to test the relation between FX returns and implied volatilities. We examine the relation between contempreneous returns and implied volatilities in section 4.4.1, and focus on the asymmetric feature of this relation in section 4.4.2. Section 4.4.3 discusses the relation between forward looking returns and implied volatilities in the currency markets.

4.4.1. Relation Between Contemporaneous Returns and Implied Volatilities

Hypothesis 19: There is a strong relation between contemporaneous returns and volatility in the FX market.

Hypothesis 20: There is a strong relation between the magnitude of the spot FX market movements, regardless of their direction, and implied volatility changes.

The following regression model is used to study the relation between the contemporaneous movements in the major FX rates and the changes in the implied volatilities.

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_i R_{i,t} + \sum \gamma_i R(ABS)_{i,t} + \varepsilon_{it} \qquad \textbf{(4-17)}$$

where,

$V_{i,t}$ is logarithmic change[15] in the implied volatility of the exchange rate i on day t, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day t-1;

[15] The results reported in this thesis use one lag. There is much debate on the correct number of lags to use in this type of analysis (Kim and Kim, 2004 used two lags and other papers have used up to 10 lags). We do consider the impact of the number of lags and as a robustness check we consider three lags, but the results do not differ significantly regardless of whether we use one or three lags.

$R_{i,t}$ is logarithmic change in the spot price movement of the exchange rate *i* on day *t*, equal to ln (P_t/P_{t-1}), where P_t denotes the closing value of the exchange rate *i* on day *t*, while P_{t-1} denotes the closing value of the exchange rate *i* on day *t-1*;

$R(ABS)_{i,t}$ is absolute value of the daily rate of return $R_{i,t}$ of the exchange rate *i* on day *t;*

ε_{it} is the error term.

The null hypothesis would be rejected in favour of the *hypothesis 19*, if the coefficient β_i *is* significantly different from zero, which would imply that the significant relation exists between contemporaneous FX returns and market volatility (this is based on Kim and Kim, 2004 for the FX future options and we test this hypothesis in the FX spot market pre and post euro)[16]. The sign of the coefficient is also important, since significantly positive β_i coefficient would indicate that positive FX returns are associated with the increase in the currency market volatility, while negative coefficient would indicate that positive returns lead to the decreased market volatility.

The second null hypothesis to be tested is that coefficient γ_i is not significantly different from zero, which indicates that there is no relation between the magnitude of the FX contemporaneous movements and daily implied volatility changes. The rejection of the null hypothesis in favour of the *hypothesis 20* would suggest that the magnitude of FX returns, regardless of their direction, is associated with volatility increases if the coefficient is positive and volatility decreases if the coefficient is negative. The test of the *hypothesis 20* would help to conclude whether Kim and Kim's (2004) findings on the currency futures market[17] can be applied to the spot currency markets. If this true, we can infer that participants in the FX market

[16] In hypothesis 19 following Kim and Kim (2004) we do not adjust for change in sign between IV and returns but we do differentiate between negative and positive returns in hypothesis 21 where we test the asymmetric relation between positive underlying FX returns and IV and negative FX returns and IV. However, this does not imply that the relation between positive returns and IV cannot be more (or less) significant than the relation between negative returns and IV.

[17] there is a strong relation between the size of the FX returns and implied volatility changes

form the expected future volatility in different ways from the participants in the equity markets[18], supporting the *hypothesis 1*.

4.4.2. Asymmetric Feature of the Return – Volatility Relation

Hypothesis 21: The impact of positive FX returns on the currency market implied volatility is different from the impact of the negative returns.

Hypothesis 22: The impact of large FX returns on the currency market implied volatility is different from the impact of small returns.

Hypothesis 23: The impact of FX returns on the currency market implied volatility on the announcement days is different from the impact of returns on the currency market implied volatility on non-announcement days.

The regression models used to study the asymmetric feature of the return – volatility relation are:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \alpha_{i-} D(-)_i + \sum \alpha_{i+} D(+)_{i+} + \sum \beta_{i-} R_{i,t} D(-)_i + \sum \beta_{i+} R_{i,t} D(+)_i + \varepsilon_{it} \quad \textbf{(4-18)}$$

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \alpha_{il} D(L)_l + \sum \alpha_{is} D(S)_{i+} + \sum \beta_{il} R_{i,t} D(L)_i + \sum \beta_{is} R_{i,t} D(S)_i + \varepsilon_{it} \quad \textbf{(4-19)}$$

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_{ia} R_{i,t} D(A) + \sum \beta_{ia2} R_{ABSi,t} D(A) + \sum \beta_{in} R_{i,t} D(N) + \sum \beta_{in2} R_{ABSi,t} D(N) + \varepsilon_{it} \quad \textbf{(4-20)}$$

where,

[18] Giot (2003) did not find any strong relation between the size of the US stock index returns and implied volatility changes

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$R_{i,t}$ is logarithmic change in the spot price movement of the exchange rate i on day t, equal to ln (P_t/P_{t-1}), where P_t denotes the closing value of the exchange rate i on day t, while P_{t-1} denotes the closing value of the exchange rate i on day $t-1$;

D(-) is a dummy variable that is equal to one when $R_{i,t}$ is negative and zero otherwise;

D(+) is a dummy variable that is equal to one when $R_{i,t}$ is positive and zero otherwise;

D(L) is a dummy variable that is equal to one when $R_{i,t}$ is larger than one standard deviation from the mean and zero otherwise;

D(S) is a dummy variable that is equal to one when $R_{i,t}$ is within one standard deviation from the mean and zero otherwise;

D(A) is a dummy variable that is equal to one when at least one announcement is made that day and zero otherwise;

D(N) is a dummy variable that is equal to one when no announcement is made that day and zero otherwise;

ε_{it} is the error term.

The rejection of the null hypothesis for β_{i-} (β_{i+}) would indicate that there is a significant relation between implied volatility of the major exchange rates and the FX negative (positive) returns. If higher market volatility is associated with the changes in the FX rates, regardless of the sign of the change, then β_{i-} coefficient should be negative, while β_{i+} coefficient should be positive[19]. However, if one of the coefficients is statistically significant, while another is not, then implied volatility would be asymmetrically related to the FX returns. In other words, the impact of

[19] Schwert (1990), Fleming et. al (1995), Dumas et. al (1998) and Giot (2003) found coefficients for both positive and negative returns being negative, which implies that negative returns cause an increase in the implied volatility, while positive returns are associated with decreased volatility.

positive returns on the FX implied volatility would be different from the impact of negative news, confirming the *hypothesis 21* above[20].

The null hypothesis that β_{il} and (β_{is}) coefficients are not significantly different from zero, would be rejected in favor of the alternative hypothesis that large (small) FX returns do have a significant impact on the market volatility. As in the case with the previous hypothesis, *hypothesis 22* would be confirmed (accepted) if one of the coefficients is statistically significant, while another is not, implying an asymmetric impact of the FX returns on the FX implied volatility.

The regression model 4-20 is designed to test a null hypothesis that the impact of the FX returns series on the FX implied volatility on the announcement days[21] is different from the impact of the FX return series on non-announcement days. *Hypothesis 20* will be accepted if one of the coefficients (β_{ia} *and* β_{in}) is statistically significant, while another is not, implying that the news announcements do have significant impact on the relation between implied volatility and returns in the FX market. The rejection of the null hypothesis that β_{ia2} (β_{in2}) coefficients are not significantly different from zero would indicate that the news announcements do have a statistically significant impact on the relation between FX market movements and the magnitude of these movements, regardless of their direction, and implied volatility changes. Due to the lack of literature on the asymmetric feature of the return – volatility relation, the test of the hypothesis 20 and 21 will provide an opportunity to contribute to the existing literature on the return - volatility relation.

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[20] We recognise that there is a scenario, in which we could find an evidence in support of the hypothesis 19 and still reject the hypothesis 21 - if the impact of both positive and negative returns are either significant or insignificant, but if there is a material difference in the magnitude of the coefficients

[21] A list of the sixteen scheduled announcements used in this empirical study is provided in Table 5-8. Due to the availability of the announcement data, the sample period of 1998 – 2003 is covered in this particular regression model.

4.4.3. Relation Between Forward Looking Returns and Implied Volatilities

Hypothesis 24: There is a significant relation between implied volatility and forward looking returns, implying that implied volatility can indicate over-bought or over-sold market conditions.

Hypothesis 25: There is a significant relation between extreme levels of implied volatility and large magnitude forward looking returns, implying that particularly high and low levels of the implied volatility can indicate over-bought or over-sold market conditions.

The regression models used to study the ability of the implied volatility to predict future returns are:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_i R(F)_{i,t} + \varepsilon_{it} \qquad \textbf{(4-21)}$$

$$V_{i,t,pos(neg)} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_i R^2(F)_{i,t,pos(neg)} + \varepsilon_{it} \qquad \textbf{(4-22)}$$

where,

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IV_t/IV_{t-1}), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;

$R(F)_{i,t}$ is logarithmic change in the price movement of the exchange rate *i* on day *t+1*, equal to ln (P_{t+1}/P_t), where P_t denotes the closing value of the exchange rate *i* on day *t*, while P_{t+1} denotes the closing value of the exchange rate *i* on day *t+1*;

$V_{i,t,pos(neg)}$ is positive (negative) logarithmic change in the implied volatility of the exchange rate *i* on day *t* higher than one standard deviation above (below) its ten year mean;

$R^2(F)_{i,t,pos(neg)}$ is squared positive (negative) logarithmic change in the price movement of the exchange rate *i* on day *t+1*;

ε_{it} is the error term.

The null hypothesis that coefficient β_i is not significantly different from zero would be rejected in favour of the *hypothesis 24,* suggesting that the FX implied volatility does indicate over bought or over sold market conditions. Given the existing findings on the significant impact of only high levels of implied volatility (Malz, 2004) on the expected asset returns, *hypothesis 25* is tested for extreme implied volatilities, whose value is higher than one standard deviation above or below its ten year mean. Similar to Malz (2000), the ability of the implied volatility to predict future returns is tested separately for positive and negative returns[22]. As the contribution to the existing literature, we focus on the predictive power of both extremely positive and extremely negative changes in the implied volatility.

Squared returns are used as a metric for returns of large magnitude. This metric focuses on the kurtosis and disregards skewness of the return distribution by ignoring the sign of the return while identifying unusually large-magnitude returns. Squared returns, rather than the return series, are used in the estimation model, because the objective of the model is to study the ability of the market volatility to predict large movements in the FX rates. This is motivated by the fact that risk managers at the financial institutions are interested in quantifying their exposures to extreme price moves, regardless of the direction of the price fluctuations.

[22] the independent variable is replaced by a series in which each observation is the squared return.

4.5. Summary

This chapter has provided a brief outline of the methodology used in our study. We discussed the regression models and hypothesis designed to test the announcement effect in the FX implied volatilities, seasonality patterns in the FX return series and implied volatilities, and finally the relation between FX returns and implied volatilities.

The results from two general hypothesis discussed in this chapter is the main source of our study's contributions to the existing literature. First of all, in all empirical chapters, we test the hypothesis that the anomalies in the FX market are different from those in the stock market, which is the focus of the vast majority of the academic papers on the financial market patterns and anomalies. Besides, we divide our ten-year sample into two five year sub-samples, to test the hypothesis that the introduction of euro in January 1999 had a material impact on the FX patterns and anomalies.

In addition, throughout the study, we test additional (less general and more specific) hypothesis in order to contribute to the existing literature. For example, we differentiate between not only positive and negative, but also between large and small returns as well as low and high volatility environment when studying the asymmetric return – volatility relation, study the FX implied volatility behavior not only on the announcement days, but also during five days prior to and following the announcements, examine and compare the impact of both US and non US holidays on the FX market and conduct additional testing of the tax loss hypothesis. The results of the hypothesis discussed in this chapter is the focus of the following four empirical chapters.

CHAPTER 5. ANNOUNCEMENT EFFECT (EMPIRICAL)

In the previous chapters, we discussed the existing literature on the announcement effect, FX seasonality patterns and the return – volatility relation in the FX market. We also described the data used in our thesis and examined the methodology employed in our study. In the remaining empirical chapters, we examine the announcement effect in the FX implied volatilities, anomalies in the FX returns and implied volatilities and study the relation between FX returns and implied volatilities. This chapter focuses on the impact of US macroeconomic news announcements and BoJ interventions on the FX implied volatilities.

We find that FX implied volatility tends to increase prior to the news announcement, tends to fall on the announcement day[1] but find the impact of the macro announcements following the announcement to be muted. We explain this by the lack of the "surprise" news and the tendency of informed traders to trade during periods of high trading activity. We contribute to the existing literature by finding that compared to DM, the Euro has become more sensitive to the macro announcements on the announcement days that we explain by an increased uncertainty caused by the introduction of Euro.

Our results indicate that the mere release of the macro indicators, rather than the surprise news, affects currency market volatility. In addition to confirming the documented sign effect, indicated by the stronger impact of bad news on the market volatility compared to the good news, we provide evidence of a weakening sign effect over time[2], which is our third contribution. Finally, we contribute to the existing literature by concluding that for eight announcements, small surprises[3] tend

[1] We observe a significant increase in the implied volatility on the BOJ intervention day, which is consistent with the existing literature and can be explained by the flow of new unexpected information into the market. We also find that it is not only the mere presence of the BOJ at the market, but also the magnitude of the interventions affects currency implied volatility – our second contribution.

[2] Relatively significant impact of positive rather than negative news for few macroeconomic indicators can be explained by the period covered by the study (1998 – 2003), which is characterized by the economic recession in USA and therefore unfavorable expectations about the macro announcements.

[3] Surprise element (difference between actual and expected results) less than one standard deviation from the mean

to have more significant impact on the FX implied volatility, and for four announcements implied volatility is affected more by the larger surprises. We explain more significant impact of small surprises by the fact that market participants are reluctant to trade after large surprises, and prefer to trade after the news releases with smaller unexpected component.

In section 5.1, we examine the impact of scheduled announcements on the FX implied volatilities, while in sections 5.2, we examine the impact of the official FOMC interest rate announcements on the FX implied volatility. In section 5.3, we focus on the BOJ interventions and its impact on the FX implied volatility. In section 5.4, we discuss the impact unexpected news have on the FX implied volatility, and focus on the asymmetric feature of this impact in section 5.5. Finally, section 5.6 provides a brief summary of the chapter.

5.1. Impact of Scheduled Announcements on the FX Implied Volatility

Table 5-1 shows that for the majority of the announcements in most of the FX rates there is some announcement effect in volatility. Typically volatility increases before the announcement of the macroeconomic indicators, declining on the day of the announcement and increasing again after the news release. Table 5-1 indicates uncertainty about the expected release of the macroeconomic indicators increases as the announcement day approaches resulting in significant volatility. As the indicator is released, the uncertainty is resolved resulting in a fall in the implied volatility (see also DeGennaro and Shrieves, 1997, and Kim and Kim, 2004). The negative sign in most cases suggests that the impact of the announced results is not very different from the expected ones. Had the surprise component of the announcements been larger it would be logical to expect a volatility rise due to the release of the new unexpected information.

We do recognize that in different market conditions, the same announcement can impact implied volatility differently. However, keeping other factors the same, positive releases of the announcements on consumer demand (trade balance, retail sales, auto sales and consumer confidence) and economic growth (construction spending report, housing starts, durable goods, Gross Domestic Product, the index of industrial production and the leading indicators) should cause USD appreciation. The inflationary indicators covered by our study (consumer price index (CPI), producers' price index (PPI), unemployment rate and non-farm payrolls) should impact USD differently – higher than expected releases should cause USD depreciation. Given their importance for the FX market, all these announcements should significantly impact the FX implied volatility.

We discuss the pre announcement, announcement and post-announcement regression results in sections 5.1.1, 5.1.2 and 5.1.3, respectively. In section 5.1.4, we discuss specific announcements, while in section 5.1.5 we check the robustness of our results.

5.1.1 Pre-Announcement

The most significant results have been obtained for the days preceding the announcement when FX implied volatility increases as the market anticipates the release of the indicators. Given that the market knows the timing of the news announcements, higher than normal (realized) volatility on the announcement day is already expected prior to the news release. This drives implied volatility up. The macro indicators that have the most significant impact on USD/EUR volatility prior to the announcement are the inflationary and some consumer demand indicators - unemployment rate, CPI, Construction Spending, Auto Sales and Non-farm Payrolls. Unemployment and Non-farm Payroll announcements (released as part of the US Employment Data Report on the same days) also have significant impact on the FX rates of US Dollar to the remaining European currencies (consistent with Cai, et. al, 2001), and CPI, Construction Spending and Leading Indicator releases significantly affect USD/GBP volatility. Auto Sales and Leading Indicators have statistically significant impact on the USD/JPY pre announcement implied volatility. These results are contrary to the conventional assumption that traders stop trading before major news announcements due to uncertainty (see Bauwens, et. al, 2005), but consistent with the private information hypothesis (see DeGennaro and Shrieves, 1997).[4] Other explanations for the pre-announcement effect are the anticipation of trades by dealers who open positions to profit from some personal beliefs and the willingness of traders to re-balance their positions to avoid announcement surprises.

5.1.2 Announcement Day

There is a tendency for the USD/EUR, USD/GBP and USD/JPY volatility to fall on the US news release days.[5] Significant impact of US Auto Sales

[4] Private information hypothesis suggests that informed traders time their trades to occur during periods of high trading activity to maximize potential profit that comes from the private information and therefore informed trading indeed causes volatility to increase. In the absence of the private information, volatility would have increased only after the news announcement, but the existence of the private information would be associated with the increased volatility prior to the announcement.

[5] The results are significant for Unemployment, Non Farm Payrolls, PPI, Retail Sales and GDP announcements in the case of USD/EUR, PPI and Retail Sales announcements in the case of USD/GBP volatility and Auto Sales announcements in the case of USD/JPY volatility.

announcements on USD/JPY volatility is mainly explained by the importance of Japanese car exports and therefore car sales in USA for the Japanese economy. The results are also in line with our expectations, given that with the release of the news announcements, the source of uncertainty disappears, unless significantly new information is released. Given that the market no longer expects higher than normal (realized) volatility, implied volatility declines. Finally, the release of most macroeconomic indicators is followed by the rise rather than fall in USD/CHF volatility (statistically significant for Construction Spending and Leading Indicators). It is difficult to explain why the volatility of the European currencies and especially USD/CHF increases on the day of some US news announcements but a possible explanation could be that these particular releases result in unexpected announcements causing an increase in the volatility on the announcement day (we will examine the impact of the unexpected element of the news release in the later section).

Although the results obtained for USD/EUR are consistent (and statistically more significant with Kim and Kim, 2004), we highlight that USD/EUR has become more sensitive to the US news announcements. This result could be explained by an increased uncertainty caused by the introduction of Euro.[6] Also Remolona, et. al, (1995) pointed out that the financial markets are more sensitive to the news releases in the period when the Fed is expected to be in a restrictive period. During the sample period of 1998 – 2004, which covers the first five years after the introduction of Euro, the major central banks were under pressure to cut interest rates due to the economic slowdown in the world's major economies and therefore this might be the cause of the increased uncertainty.

5.1.3 Post-Announcement

The post announcement volatility change is not as significant as the volatility prior to the news announcement. The results are significant for the announcement of two macroeconomic indicators in the case of USD/EUR (GDP and CPI) and six

[6] Dominguez and Panthaki (2005) found news that arrives during periods of high uncertainty have more significant effects on the FX rates than news that arrives in calmer periods.

indicators in the case of USD/GBP (GDP, CPI, Beige Book, Unemployment, Non-farm Payrolls and Durable Goods). The results are muted, given that unless a news announcement contains materially new information, implied volatility should not change significantly post the announcement days – the source of uncertainty is gone and after the implied volatility adjustment, nothing should affect the implied volatility. However, given that many announcement contain at least some new information, the FX implied volatility tends to increase after the news announcements, as the market reevaluates its perception of the short and long-term market outlook based on the new information. It would take some time for the analysts to react to the news announcements and express their opinion about the market. The change in the market outlook causes increased uncertainty resulting in the volatility rise on the days following the announcement. Although USD/JPY volatility is not affected by the US news releases prior to and on the day of the announcements the impact of four US news releases on the post announcement volatility is significant. The volatility of USD/JPY FX rate tends to increase after the announcement of Durable Goods and Current Account figures, but tends to fall after the release of Construction Spending and Auto Sales figures.[7] All four indicators and especially current account and auto sales, directly or indirectly provide a signal to the market about the Japanese exports.

5.1.4 Specific News Announcements

We find there is no specific impact of trade balance announcements on the FX implied volatility. Although, this result supports some earlier studies (see Ederington and Lee, 1996), they contradict Andersen and Bollerslev (1998), and Kim, et. al, (2004). The inconsistency between the results could be due the use of the intra-daily rather than the daily data in this study that provides a stricter test of finding an impact and/or the differences in the sample periods. This study focuses on the post

[7] This supports the findings of Kim, et. al, (2004) who suggest that the impact of US news releases on USD/JPY is weaker than that on the rates of US dollar to European currencies. This phenomenon could be explained by the geographic and timing factors. Because of the time differences, European markets are still open when most US news are announced driving the volatility of the European currencies up. However, the Japanese market is closed when US news is released, and therefore the reaction of the Japanese market to the US news releases is extended over time: the reaction occurs first when the news are released, and later when Japanese market opens.

1998 period, which mainly covers the post Euro period, but the most recent similar study by Kim, et. al, (2004) covered a period prior to the introduction of Euro in January 1999. If the impact of the trade balance announcements on the FX implied volatility weakened over time, then it would be reasonable to expect the insignificant trade balance coefficients reported in our study.[8] The relation between trade balance figures and the US central bank intervention policy can also have an impact on our results. Although the introduction of Euro is unlikely to explain the weakening impact of the trade balance announcements on the FX implied volatility, it could still indirectly contribute by its influence on the central bank intervention policy (see Deravi, et. al, 1988). Since the interventions have become less common reducing the market expectations of any intervention regardless of the announced trade deficit figures, one would expect the impact of trade balance announcement on the FX volatility to become less significant.

Among the inflation indicators, PPI follows the same pattern as most indicators with the reduced volatility on the announcement days and increased volatility on days preceding and following the announcements. However, CPI is associated with reduced volatility both prior to and following the announcement. This result could be explained as both indicators are perceived to have the same information content, and the market reacts to the indicator released first. Since PPI is released five to six days prior to CPI, the market perceives PPI announcement as a main news release and CPI announcement as a confirmation signal. In other words, a significant fall in the volatility following PPI release distorts the results obtained for CPI.[9]

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[8] A limited number of papers have studied the impact of Euro adoption as a single currency on the FX volatility (various commentators have suggested very different predictions on the impact on volatility).

[9] Nikkinen and Sahlstrom (2004) came to the similar conclusion that the market mainly reacts to the PPI release. They also concluded that the market regards their information content to be significant. Andersen, et. al, (2003) also suggested that PPI news explain more FX rate return variation than CPI news, as the typical amount of the new information showed with CPI release is relatively small given the PPI news showed earlier in the month.

5.1.5 Robustness Checks

We check the robustness of the results by including dummy variables denoting the days of the week apart from Wednesday (to avoid the dummy variable trap). The regression results reported in the Table 5-1 suggest that the significant announcement effect detected when the day of the week effect is not controlled for weakens when the day of the week variables are included in the regression model. However, the impact of the US news announcements on the FX implied volatility is still significant even after controlling the intraweek seasonality patterns.

5.2. Impact of the Interest Rate Announcements on the FX Implied Volatility

Table 5-2 shows that FOMC minutes tend to have similar impact as the macro-announcements – FX volatility tends to increase prior to the FOMC minutes (although not significantly). Since the days of the FOMC meetings are known in advance the market reacts to the forthcoming event causing a jump in the implied volatility. On the day of the Fed rate announcement, FX volatility falls significantly for three of our FX rates as the source of uncertainty disappears. The impact of FOMC announcements is more significant than that of the announcement of most macroeconomic indicators, which is not surprising given the importance of the interest rate changes for the US and global economy and therefore for the volatility of US Dollar.[10] Volatility increases again after the announcement day for three FX rates, probably due to the change in the market outlook caused by the release of a new information.

We also examine how FX market reacts to the announcement of the actual interest rate changes (US Fed Rate Changes). Within the context of our study, the main difference between FOMC minutes and interest rate changes is that the interest rate changes are not always anticipated although FOMC announcements dates are known in advance. Although the Fed is reluctant to set a new official interest rate without scheduled meeting, the announcement of the majority of eleven changes were not scheduled. We note that since the market does not always anticipate the change in the official interest rate, the FX implied volatility changes prior to the interest rate announcements are not statistically significant. Although FX volatility tends to fall on the day of the FOMC announcement, the announcement of the interest rate changes do not have significant impact on the volatility of the three major FX rates (statistically significant for USD/GBP only). This result could be explained by the fact that the impact of the expected and unexpected interest rate announcements offset each other - volatility tends to fall after the release of the anticipated interest rate change following the scheduled FOMC meeting (as the

[10] After observing statistically significant drop in volatility on the days of FOMC announcement, Nikkinen and Sahlstrom (2004) also concluded that investors regard FOMC announcement as highly significant.

source of uncertainty created by the FOMC, whose timing is known in advance, disappears) and increase after the unscheduled announcement of the new official interest rate (as new information is released, acting of a source of the incremental uncertainty).

5.3. Impact of the BOJ Interventions on the FX Implied Volatility

In Section 5.3.1, we examine the impact of BOJ interventions on the FX implied volatilities. In section 5.3.2, we differentiate between the impact of Yen purchases and Yen sales by BOJ on the FX implied volatilities, while in section 5.3.3, we examine whether the mere presence of the BOJ or the magnitude of its interventions impact FX implied volatilities. Finally, in section 5.3.4, we check the robustness of our results.

5.3.1. BOJ Interventions

The results in Table 5-2 suggest that there is a positive correlation between the interventions of the BOJ and the anticipated volatility for USD/EUR and USD/JPY (for USD/CHF and USD/GBP the regression coefficient is also positive, albeit not significantly different from zero), supporting the hypothesis 3. In the case of the scheduled news announcements, investors anticipate the news release and therefore overreact to the forthcoming event causing a jump in the implied volatility. However, the same reasoning cannot be applied for the central bank interventions, since the intervention is not usually anticipated, although there are always some rumors, which leads to the presence of informed traders who exploit their privileged information as suggested by Degennaro and Shrieves (1997). Indeed, it is possible to suggest that central bank could intervene in the FX market just as the response to the increased volatility conditions in the exchange rate market to calm "disorderly markets". Since many of the BOJ interventions have been conducted in cooperation with other G7 central banks, like Fed and ECB, statistically significant results have been obtained for the exchange rates of US Dollar to the European currencies. This conclusion is consistent with the findings by Connolly and Taylor (1994) who observed that the FX volatility prior to the BOJ interventions in late 1970s tend to be greater than usual and Ramchander and Sant (2002) who suggested that Fed is more actively involved in the FX market during periods of higher volatility. In addition, Mussa (1979) suggests that uncertainty about central bank policies may help to explain why we observe alternate periods of 'quiescence' and 'turbulence' in the exchange rate movements.

On the day when central bank actually intervenes, implied volatility of all the exchange rates increases significantly[11]. This result is opposite to the results obtained for the scheduled news announcements and is consistent with the existing findings[12] that volatility increases after unscheduled news releases and falls after scheduled news announcements. The findings are consistent with the results reported in the existing literature that used financial press intervention releases as a proxy for BOJ interventions (Connolly and Taylor, 1994, Bonser-Neal and Tanner, 1996, Dominguez, 1998 and Galati and Melick, 1999) and more recent work that used official interventions data released by BOJ (Frenkel et. al, 2003). The results are also consistent with the literature on the correlation between FX volatility and the interventions conducted by other central banks[13]. This increase in volatility is due to rumors of an intervention circulating for a certain period of time from one dealer to another – acting as the source of uncertainty - until they become widely disseminated and are broadcasted by a specialized news agency.

Both the inventory-based approach and the information-based approaches in the microstructure literature could explain the finding of a positive relation between BoJ interventions and the FX market volatility in the short run. The inventory-based approach (O'Hara, 1995 and Lyons, 2001) emphasizes the balancing problem on foreign exchange markets resulting from stochastic inflows and outflows deviations, resulting from a policy intervention. According to this approach, these deviations will be temporary and last until portfolios have been rebalanced. The information-based approach focuses on the process of learning and price formation on markets. In high volatility periods, much trading can take place as informed trades can easily hide the volume of their transactions. This approach predicts an increase in

[11] results are significant for USD/GBP at 1% significance level and at 5% significance level for USD/EUR, USD/CHF and USD/JPY
[12] Edderington and Lee (1996), Frankel et. al (2003), Kim et. al (2004)
[13] Bonser-Neal and Tanner (1996), Baillie and Osterberg (1997), and Bauwens et. al (2005) studied US central bank interventions, while Baillie and Humpage (1992) focused on the Fed and Bundesbank interventions

transactions volume and volatility following a central bank intervention. Once the intervention news has been revealed, transaction volume, prices and volatility should revert to their pre-intervention levels. Longer-run effects are related to factors such as information processing, while more volatile market conditions might require more time to revert to their initial levels.

The difference between the reaction of the FX volatility to the announcement of the scheduled news releases and central bank intervention is the unawareness of the market about the event. While the market already anticipates the announcement of the scheduled news like the announcement of the macroeconomic indicators, the market is unaware of the central bank interventions before they occur, and sometimes even after they occur. It is possible that the less market knows about central bank interventions, the more likely volatility would increase as the result of this intervention. Given that some of the central bank interventions conducted by the central bank do not even become public news, it could be expected that such "secret" interventions, which are never publicly announced tend to cause larger increase in the volatility than the interventions reported in the financial press. The main reason is that such "secret" interventions are less well understood by the market participants (and the financial press). This misunderstanding could explain why the results of this study are much more statistically significant than the results of Bonser-Neal and Tanner (1996) and Ramaswamy and Samiei (2000), who used financial press intervention releases as the proxy for BOJ interventions.

The results also suggest that FX volatility tends to fall following BOJ intervention days, though the coefficients are significant only for USD/JPY at 5% significance level. These results are in line with Bauwens et. al (2005), who concluded that once the intervention rumor is refuted or confirmed, volatility drops immediately. As it takes some time for the specialized agencies to treat rumor seriously and announce them, the market reacts to the news, resulting in the volatility fall following the intervention day. Andersen and Bollerslev (1998) concluded that while the impact of the scheduled news announcements on the FX volatility appear to be short lived, unscheduled news tend to have more prolonged impact on the FX volatility. Although, Andersen and Bollerslev (1998) used volatilities implied from the 5 minute FX return series rather than daily observations, this conclusion explains why the decrease in the volatility following BOJ interventions is more significant than the change in the FX volatility following scheduled news releases.

5.3.2. Yen Purchases versus Yen Sales

The results presented in Table 5-3 suggest that the impact of FX interventions by the BOJ are driven by Yen sales rather than Yen purchases: the impact of the Yen sales by the BOJ on the volatility of all major exchange rates is statistically significant, while the impact of Yen purchases is statistically insignificant. However, in the period of 1998 – 2003 covered by this study, only in three out of the total 117 interventions, the BOJ acted as the buyer of Yen. This could be expected since strong Yen is not beneficial for the Japanese exports, but the small sample size does not allow us to make reliable conclusion. Nevertheless, the findings by Frenkel et. al (2003) concerning the impact of the BOJ purchases and sales of US Dollar against Yen on the implied volatility of USD/JPY exchange rate are identical to our findings.

5.3.3. Presence versus Magnitude

Although Frenkel et. al (2003) concluded that it is the presence of the BOJ in the market, not the magnitude of its interventions that causes significant changes in the FX volatility, our results suggest that there is a positive relationship between FX volatility and the magnitude of BOJ interventions, supporting the hypothesis 5. This relationship is statistically significant for all exchange rates, but USD/CHF (Table 5-3).

The results suggest that both the presence and the magnitude of the BOJ interventions do have significant impact on the implied volatility of at least three major exchange rates. This result could be expected (given that large interventions should have a more significant impact on the implied volatility) and is our main contribution to the existing literature on the impact of the central bank interventions on the implied volatility. There could be few explanations for the discrepancy between our results and the findings of Frenkel et. al (2003). The most obvious one is the fact that although there is two year overlapping period between sample periods covered, Frenkel et. al (2003) covered 1993 – 2000 period, while our study covers 1998 – 2003 period. Secondly, while the study by Frenkel et. al (2003) focused on the purchase and sales of US Dollar only (prior to the introduction of Euro, BOJ used USD as the main counterparty for Yen sales/purchases), we also use a data on BOJ interventions where Euro was involved. Finally, there is a concern over the methodology employed by Frenkel et. al (2003). To account for the size of the money supply, we use the relative value of the intervention magnitude to the Japanese money supply. Frenkel et. al (2003) regressed several independent variables, including the dummy variable denoting the intervention days and the variable denoting the absolute amount of the BOJ interventions (ignoring money supply could undermine the accuracy of the results as money in 1998 was not the same as money in 2003), against a dependant variable denoting the logarithmic changes in daily implied volatility series. Using several independent variables in the regression is acceptable as long as they are not correlated. However, when the independent variables are correlated with one another, multicollinearity condition arises, resulting in the inaccurate results due to the large sampling variability of the estimated regression coefficients. It would be quite logical to suggest that the independent variables used by Frenkel et. al (2003) regression are highly correlated. At least for this particular study, the correlation coefficient between these two variables is 0.66, which is significant enough to cause multicollinearity.

5.3.4. Robustness Checks

We check for any macro announcement effect, by including into the model the additional dummy variable that takes the value of one on the day when any of the scheduled announcements (listed in Table 3-8) is released, and zero otherwise.[14] We also control for the day of the week seasonality effects. The coefficients reported in

[14] Since fifty-seven out of one hundred and seventeen days on which the BOJ conducted interventions, are also the macro announcements days, it is possible that the results could be caused by the announcement effect, as opposed to the central bank intervention.

Table 5-2 suggests that the results indicating the significant impact of the central bank interventions on the FX volatility prior to, during and following the intervention do not change significantly after accounting for macroeconomic announcements and intraweek seasonality patterns.

5.4. Impact of Unexpected Announcements on the FX Implied Volatility

Table 5-4 shows there are five macroeconomic indicators (GDP, durable goods, consumer confidence, industrial production and leading indicators) where the impact of the announcement's surprise element on the FX volatility is statistically significant. Four out of five indicators are the economic growth announcements, whose content appear to be more important for the financial community than the content of the inflationary and consumer demand releases. Given we use daily data rather than intra-day data it is clear the unexpected impact of these announcements is an important influence on volatility. However, for the other ten announcements the mere presence of an announcement has stronger impact on the FX volatility than the size of the associated surprise. Possible explanations are that either the announcements do not contain material unexpected information or the surprise element is not sufficient to significantly move the FX implied volatility.

We report positive coefficients for durable goods, consumer confidence and leading indicators, suggesting that the higher the unexpected portion of the announcement, the higher the FX volatility. However, the relation between the content of GDP and industrial production releases (which have similar information content) and implied volatility is negative implying that larger surprises appear to reduce FX volatility and could be explained by the increased uncertainty accumulated prior to the GDP and industrial production announcements and the subsequent significant drop in the volatility on the announcement day. The importance of these announcements makes this fall in volatility offset an increased uncertainty due to a lack of market consensus regarding the news arrival, resulting in the negative regression coefficients.

Table 5-4 suggests that there is no strong evidence for the asymmetric feature of the announcement effect[15]. These findings are not consistent with Hogan, et. al, (1991) and Madura and Tucker (1992), who concluded that trade balance releases with the large surprise announcements tend to have more significant impact on the

[15] For eight (four) macroeconomic indicators the impact of the news releases on the FX volatility is caused by the announcements with small (large) surprise elements for at least one FX rate.

FX volatility, but are in line with Aggarwal and Schirm (1998), who reported similar results for the equity and FX return series. Aggarwal and Schirm (1998) suggested that central banks have access to the macroeconomic figures (e.g. trade balance) prior to the announcements and can intervene in the market if the magnitude of the unexpected component of the release is too big, making others market participants reluctant to trade. If the surprise element is not big, a central bank seems to be unwilling to spend resources for the intervention, attracting other participants to the market. Therefore, the announcements with the large unexpected component make the majority of the participants reluctant to trade due to the fear of the central bank intervention or even the fear of major market players closing open positions in response to the significantly unexpected news. Since the market does not expect significant interventions and shocks, following the news announcements with the small surprise element, the market participants prefer to trade after the news releases with small unexpected component, which drives implied volatility up.

Table 5-4 also shows that for five out of total fifteen indicators, the unfavorable news announcements have statistically significant impact on the implied volatility of at least one FX rate. Positive (the realized figure is larger than the expected one) releases of trade balance and non-farm payroll indicators, and negative (the realized figure is smaller than the expected one) releases of durable goods, leading indicators and auto sales indicators (which imply a slowdown of the economy) have a significant impact on the FX volatility. The results confirm the existence of the sign effect, indicated by relatively stronger impact of negative (as opposed to positive) news, documented by Laakkonen (2004) and to some degree by Bauwens, et. al, (2005).[16]

We also find an evidence of a relatively stronger impact of positive news for four macro announcements (statistically significant for GDP, industrial production and construction spending for at least one FX rate). This finding suggests that in spite

[16] Although Bauwens, et. al, (2005) concluded that there is no strong evidence in favor of a difference in the revealed volatility reaction between positive and negative US macroeconomic announcements; their results suggest that volatility increases by ten percent prior to the release of positive macroeconomic figures and by around twenty percent prior to negative macroeconomic announcements.

of the evidence of the negative surprises having greater volatility impact than positive surprises, it seems that the sign effect had weakened over time. We try to explain the weakening sign effect by the dynamics of uncertainty regarding the underlying state of the economy, which tends to drive the asymmetry (Andersen, et. al, 2003). Two major strands of literature, which try to explain asymmetry in the response of FX rates to news, imply that negative news in good times should have unusually large impact on the FX market volatility (a view that is also common in the practitioner community). The main idea of both strands is that when the economic conditions are favorable, bad news generates strong response, because it is a surprise, causing a volatility jump, but good news generates weak response because it is anticipated. Given that, most studies on the sign effect covered 1990s, the period characterized by favorable market conditions; it is not surprising that the evidence of the strong sign effect has been obtained. However, the post Euro period covered by our study (1998 – 2003) coincides with the slowdown in the major economies, and therefore makes bad news to be expected to some degree. As the result, the volatility impact of negative releases of most macroeconomic indicators in 1998 – 2003 period is weaker than the impact of the same indicators in the pre-Euro era. In addition, the sign effect reverses for the indicators like GDP and industrial production. This finding could also be expected, given that the main sign of the economic slowdown in USA was the declining GDP growth rate and industrial production figures. As the market expects GDP and industrial production releases to be negative, good news become more important than bad news because of the surprise element. As the result, positive rather than negative GDP, industrial production and construction spending announcements causes significant increase in the FX volatility.

5.5. Summary

Understanding of the implied volatility patterns is important because of its role in risk management and trading. This chapter investigates the impact of the announcement of sixteen major US macro indicators, the FOMC minutes, the official US interest rates and the BOJ interventions on the implied volatility of four major FX rates from 1998-2003. The results indicate that FX market volatility tends to increase five days prior to the announcement for the majority of the US macro indicators. Volatility tends to fall on the announcement day for most macroeconomic indicators but the impact of the macro announcements during five days following the announcement day is muted. This result could be explained by the lack of the "surprise" news and the tendency of informed traders to trade during periods of high trading activity to maximize potential profit that comes from the private information. We contribute to the existing literature by finding that compared to DM, the Euro has become more sensitive to the macro announcements on the announcement days. This result could be explained by an increased uncertainty caused by the introduction of Euro. We also find evidence of a changing announcement effect over time.

We find the impact of the FOMC minutes on the implied volatility to be similar to that of the macroeconomic indicator announcements. Since the impact of the expected and unexpected announcement of the interest rate changes offset each other, the announcement of the interest rate changes do not have significant impact on the volatility of three out of four major FX rates examined. Although implied volatility tends to behave similarly prior to the BOJ interventions, with the volatility of USD/EUR and USD/JPY displaying a significant rise prior to the event, unlike the sixteen macro announcements, interventions are not followed by the fall in the volatility. A significant increase in the FX implied volatility on the BOJ intervention day supports the existing literature and can be explained by the flow of new unexpected information into the market. We also find that it is not only the mere presence of the BOJ at the market, but also the magnitude of the interventions affects currency implied volatility.

We conclude that the impact of macro announcements' surprise element on the FX volatility is not significant for most indicators using daily data, implying that the mere release of the macro indicators, rather than the surprise news, affects currency market volatility. In addition to confirming the documented sign effect, indicated by the stronger impact of bad news on the market volatility compared to the good news, we provide evidence of a weakening sign effect over time. Relatively significant impact of positive rather than negative news for few macroeconomic indicators can be explained by the period covered by our study (1998 – 2003), which is characterized by the economic recession in USA and therefore unfavorable expectations about the macro announcements. Further, we contribute to the existing literature by concluding that for eight announcements, small surprises tend to have more significant impact on the FX implied volatility, and for four announcements implied volatility is affected more by the larger surprises. We explain more significant impact of small surprises by the fact that market participants are reluctant to trade after large surprises, and prefer to trade after the news releases with smaller unexpected component.

Table 5-1. Impact of the Scheduled Macro Announcements on the FX Volatility

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	Bi	t-stat.	βi	t-stat.	βi	t-stat.	Bi	t-stat.
Trade Balance (72 announcements)								
Constant	0.0002	0.21	0.0005	0.38	0.0004	0.28	-0.0007	-0.54
TB	0.0008	0.21	-0.0076	-1.54	-0.0048	-0.74	-0.0063	-1.17
Lag	-0.0008	-0.38	-0.0003	-0.10	-0.0027	-0.77	0.0039	1.38
Fwd	-0.0005	-0.25	-0.0013	-0.47	0.0014	0.404	0.0004	0.12
Unemployment (72 announcements)								
Constant	-0.0016	-1.72*	-0.0017	-1.42	-0.0009	-0.59	-0.0004	-0.28
Unemployment	-0.0087	-2.17**	-0.0057	-1.15	-0.0079	-1.25	-0.0079	-1.45
Lag	0.0086	4.26***	0.0069	2.65***	0.0058	1.75*	0.0008	0.31
Fwd	0.0029	1.36	0.0044	1.58*	0.0018	0.52	0.0017	0.59
CPI (72 announcements)								
Constant	0.0015	1.55	0.0015	1.26	0.0009	0.6	-0.0004	-0.34
CPI	-0.0007	-0.16	0.0028	0.56	0.0009	0.14	-0.0029	-0.54
Lag	-0.0037	-1.78*	-0.0050	-1.86*	-0.0041	-1.19	0.0007	0.24
Fwd	-0.0051	-2.4**	-0.0060	-2.2**	-0.0017	-0.49	0.0013	0.44
PPI (72 announcements)								
Constant	0.0001	-0.1	-0.0002	-0.21	-0.0006	-0.38	-0.0008	-0.62
PPI	-0.0097	-2.42**	-0.0132	-2.68***	-0.0034	-0.53	-0.0045	-0.84
Lag	0.0006	0.28	0.0005	0.18	0.0027	0.81	0.0019	0.687
Frw	0.0025	1.15	0.0040	1.47	0.0022	0.62	0.0025	0.88
Retail Sales (72 announcements)								
Constant	0.0006	0.58	0.0003	0.29	0.0003	0.22	-0.0007	-0.57
Retail Sales	-0.0129	-3.2***	-0.0099	-2.00**	-0.0080	-1.26	-0.0063	-1.17
Lag	-0.0014	-0.65	-0.0019	-0.70	-0.0009	-0.26	0.0003	0.103
Frw	0.0011	0.51	0.0017	0.63	0.0012	0.33	0.0044	1.52
Durable Goods (72 announcements)								
Constant	-0.0005	-0.52	-0.0008	-0.69	-0.0009	-0.58	-0.0002	-0.133
Durable Goods	-0.0027	-0.66	-0.0046	-0.9	0.0019	0.31	-0.0087	-1.6
Lag	0.0018	0.84	0.0015	0.54	0.0018	0.52	-0.0028	-1.01
Frw	0.0021	0.97	0.0044	1.62*	0.0037	1.08	0.0045	1.59*
Construction Spending (72 announcements)								
Constant	-0.0007	-0.71	-0.0012	-0.97	-0.0006	-0.42	0.0001	0.07
Construction Sp.	0.0051	1.28	0.0037	0.75	0.0110	1.84*	0.0010	0.18
Lag	0.0037	1.74*	0.0048	1.75*	0.0024	0.71	0.0033	1.18
Frw	-0.0005	-0.24	0.0012	0.46	-0.0010	-0.29	-0.0056	-1.97**
GDP (72 announcements)								
Constant	-0.0007	-0.69	-0.0014	-1.21	-0.0009	-0.62	0.0000	-0.01
GDP	-0.0121	-3.00***	-0.0071	-1.44	0.0022	0.35	-0.0086	-1.59
LAG	0.0017	0.82	0.0014	0.5	0.0010	0.29	-0.0035	-1.25
FRW	0.0055	2.57***	0.0093	3.41***	0.0048	1.39	0.0043	1.51

Current Account (72 announcements)								
Constant	-0.0004	-0.49	-0.0006	-0.55	-0.0001	-0.11	-0.0009	-0.83
Current Account	0.0020	0.29	-0.0009	-0.11	0.0126	1.17	-0.0108	-1.18
Lag	0.0028	0.81	0.0048	1.1	0.0030	0.53	0.0040	0.88
Frw	0.0048	1.42	0.0048	1.08	-0.0026	-0.467	0.0111	2.44**
Auto Sales (71 announcements)								
Constant	-0.0010	-1.02	-0.0009	-0.79	-0.0006	-0.42	0.0003	0.204
Auto Sales	0.0060	1.49	0.0058	1.16	0.0093	1.47	-0.0104	-1.91*
Lag	0.0048	2.26**	0.0041	1.51	0.0025	0.72	0.0048	1.69*
Frw	0.0001	0.025	0.0000	-0.01	-0.0005	-0.14	-0.0055	-1.95**
Beige Book (41 announcements)								
Constant	0.0007	0.83	0.0004	0.39	0.0003	0.25	0.0003	0.22
Beige Book	-0.0048	-0.91	0.0013	0.21	-0.0101	-1.22	-0.0035	-0.49
Lag	-0.0023	-0.87	0.0004	0.125	0.0005	0.12	-0.0012	-0.32
Frw	-0.0040	-1.53	-0.0067	-1.96**	-0.0014	-0.31	-0.0034	-0.96
Consumer Confidence (72 announcements)								
Constant	-0.0003	-0.32	0.0001	0.12	0.0001	0.08	0.0002	0.148
Consumer Conf.	-0.0038	-0.94	-0.0004	-0.08	0.0017	0.28	-0.0025	-0.46
Lag	0.0042	1.98	0.0018	0.645	0.0018	0.514	-0.0016	-0.56
Frw	-0.0012	-0.57	-0.0033	-1.19	-0.0029	-0.82	-0.0005	-0.17
Industrial Production (72 announcements)								
Constant	0.0010	1.01	0.0012	0.986	0.0004	0.24	-0.0004	-0.31
Industrial Prod.	-0.0034	-1.40	-0.0053	-1.08	-0.0095	1.50	0.0024	0.455
Lag	-0.0029	-1.39	-0.0032	-1.18	0.0012	0.34	-0.0005	-0.17
Frw	-0.0021	-0.98	-0.0036	-1.32	-0.0009	-0.27	0.0009	0.32
Leading Indicators (72 announcements)								
Constant	-0.0003	-0.34	-0.0011	-0.89	-0.0005	-0.29	-0.0009	-0.67
Leading Ind.	0.0004	0.09	0.0029	0.58	0.0143	2.27**	-0.0069	-1.27
Lag	0.0025	1.17	0.0064	2.35**	0.0024	0.71	0.0076	2.69***
Frw	-0.0004	-0.18	-0.0008	-0.31	-0.0028	-0.83	-0.0020	-0.715
Non-Farm Payrolls (72 announcements)								
Constant	-0.0016	-1.72*	-0.0017	-1.42	-0.0009	-0.59	-0.0004	-0.28
Non-farm Payr.	-0.0087	-2.17**	-0.0057	-1.15	-0.0079	-1.25	-0.0079	-1.45
Lag	0.0086	4.26***	0.0069	2.65***	0.0058	1.75*	0.0008	0.309
Frw	0.0029	1.36	0.0044	1.58*	0.0018	0.52	0.0017	0.59
Housing Starts (72 announcements)								
Constant	0.0004	0.47	0.0004	0.328	0.0001	0.062	-0.0010	-0.82
Housing Starts	-0.0031	-0.77	-0.0023	-0.46	-0.0010	-0.16	-0.0036	-0.67
Lag	-0.0003	-0.13	-0.0001	-0.03	0.0028	0.8	0.0039	1.37
Frw	-0.0017	-0.78	-0.0025	-0.91	-0.0028	-0.82	0.0020	0.71
Annoucement Effect (with DoW)								
Constant	0.0027	2.83***	0.0022	1.76*	0.0005	0.30	0.0033	2.53**
D(A)	-0.0069	-4.46***	-0.0055	-2.81***	-0.0010	-0.42	-0.0089	-4.34***
Constant	0.0039	1.69*	0.0005	0.20	0.0009	0.28	0.0030	1.02
D(A2)	-0.0043	-2.31**	-0.0035	-1.64*	0.0003	0.11	-0.0073	-2.82***

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

LAG –five days prior to the announcement
FRW –five days following the announcement

The estimation is based on the following model:

$$\mathbf{V}_{i,t} = \alpha_0 + \alpha_i \mathbf{A}_{i,k,t} + \sum_{t=0}^{5} \beta_i \mathbf{A}_{i,k,t-5\ldots t-1} + \sum \gamma_i \mathbf{A}_{i,k,t+1\ldots t+5} + \varepsilon_{i,t}$$

$$\mathbf{V}_{i,t} = \alpha_0 + \alpha_i \mathbf{D(A)}_{i,t} + \beta_i \mathbf{D(A2)}_{i,t} + \varepsilon_{it}$$

where:
$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;
$A_{ik,,t}$ is the dummy variable that takes value of one if the macroeconomic announcement k takes place in a period t, and zero otherwise
$A_{ik,,t-5\ldots t}$ and $A_{ik,,t+5\ldots t}$ are the series of five dummy variables that take value of one on each of five days preceding and following the macroeconomic announcement k and zero otherwise. The regression coefficients for the dummy variables $A_{ik,,t-5\ldots t}$ and $A_{ik,,t+5\ldots t}$ are reported in rows *Lag* and *Frw*, respectively
D(A) is the dummy variable that takes value of one if any of the macroeconomic announcements takes place in a period t, and zero otherwise
D(A2) is the dummy variable that takes value of one if any of the macroeconomic announcements takes place in a period t, and zero otherwise, in the model where day of the week effect is accounted for
ε_{it} is the error term

Table 5-2. Impact of Unscheduled News Announcements on the FX Volatility

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β_i	t-stat.	B_i	t-stat.	β_i	t-stat.	B_i	t-stat.
	FOMC Minutes (25 announcements)							
Constant	0.0001	0.16	-0.0008	-0.70	-0.0002	-0.17	-0.0004	-0.36
FOMC	-0.0097	-1.89*	-0.0157	-2.50***	-0.0144	-1.80*	-0.0122	-1.76
Lag	0.0018	0.71	0.0054	1.60	0.0062	1.46	0.0024	0.68
Fwd	-0.0008	-0.31	0.0061	1.80*	0.0006	0.15	0.0024	0.67
	US Fed Rate Changes (23 announcements)							
Constant	0.0004	0.46	0.0001	0.14	0.0005	0.36	0.0005	0.46
Fed Rate	0.0003	0.05	0.0150	1.75*	-0.0010	-0.10	-0.0066	-0.70
Lag	-0.0021	-0.57	-0.0039	-0.81	-0.0060	-0.99	-0.0071	-1.48
Fwd	-0.0057	-1.55	-0.0062	-1.31	-0.0034	-0.56	-0.0070	-1.44
	Interventions (114 interventions)							
Constant	-0.0005	-0.62	-0.0006	-0.54	-0.0011	-0.77	-0.0010	-0.88
Interventions	0.0068	2.13**	0.0120	3.07***	0.0103	2.09**	0.0105	2.43**
Lag	0.0055	1.88*	0.0002	0.05	0.0032	0.68	0.0094	2.39**
Fwd	-0.0038	-1.30	-0.0043	-1.13	0.0024	0.51	-0.0076	-1.93**
	Interventions (with DoW and Announcement Effect)							
Constant	0.0033	1.55	-0.0001	-0.04	-0.0002	-0.06	0.0026	0.91
Interventions	0.0070	2.21**	0.0119	3.05***	0.0089	1.8*	-0.0032	-0.75
Lag	0.0049	1.69*	-0.0004	-0.10	0.0034	0.74	0.0151	3.87***
Fwd	-0.0036	-1.25	-0.0039	-1.02	0.0033	0.71	-0.0076	-1.91*

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

LAG –five days prior to the announcement
FRW –five days following the announcement

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i A_{i,k,t} + \sum \beta_i A_{i,k,t-5...t} + \sum \gamma_i A_{i,k,t+5...t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;

$A_{ik,,t}$ is the dummy variable that takes value of one if the unscheduled announcement k takes place in a period t, and zero otherwise

$A_{ik,,t-5...t}$ and $A_{ik,,t+5...t}$ are the series of five dummy variables that take value of one on each of five days preceding and following the unscheduled announcement k and zero otherwise. The regression coefficients for the dummy variables $A_{ik,,t-5...t}$ and $A_{ik,,t+5...t}$ are reported in rows *Lag* and *Frw*, respectively

ε_{it} is the error term

Table 5-3. Impact of the BOJ Intervention on the FX Volatility

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β_i	t-stat.	B_i	t-stat.	β_i	t-stat.	β_i	t-stat.
	Intervention Magnitude							
Constant	-0.0002	-0.265	-0.0006	-0.73	-0.0001	-0.14	-0.0007	-0.54
M	0.97256	1.90*	2.43263	4.03***	0.83474	1.11	1.2365	1.93***
	Purchase/Sale of Yen							
Constant	-0.0004	-0.48	-0.0009	-0.91	-0.0006	-0.48	-0.0008	-0.79
B	-0.0074	-0.38	0.0116	0.50	-0.0014	-0.05	-0.0030	-0.12
S	0.0070	2.17**	0.0095	2.40**	0.0098	1.97**	0.0108	2.47***

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

The estimation is based on the following model:
$$V_{i,t} = \alpha_0 + (1) \sum \alpha_i M_t + (2) \sum \alpha_{i2} B_t + \sum \alpha_{i3} S_t + \varepsilon_{it}$$

where:
$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;
M_t denotes the absolute amount of the BOJ intervention on day t
B_t and S_t are the dummy variables that takes value of one if BOJ buys (sells) Japanese Yen and zero otherwise
ε_{it} is the error term

Table 5-4. Impact of Surprise Element of the Macro Announcements on the FX Volatility

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β_i	t-stat.	B_i	t-stat.	β_i	t-stat.	β_i	t-stat.
Trade Balance (72 announcements)								
Constant	0.00001	0.01	0.0001	-0.09	0.00005	0.04	-0.0002	-0.22
TB	0.0588	1.34	0.0167	0.31	-0.009	-0.13	-0.0656	-1.11
Large	0.0625	1.28	0.0138	0.23	0.0064	0.09	-0.0901	-1.37
Small	0.0432	0.43	0.0290	0.23	-0.084	-0.51	0.0372	0.27
Positive	0.1267	1.89*	-0.0071	-0.08	-0.0898	-0.85	-0.1084	-1.2
Negative	0.0065	0.11	0.0351	0.48	0.0519	0.56	-0.0326	-0.41
Unemployment (72 announcements)								
Constant	0.00005	0.07	0.00007	-0.07	0.00002	0.01	-0.0002	-0.19
Unemployment	-0.0317	-1.14	-0.0179	-0.53	0.0254	0.56	-0.0428	-1.14
Large	-0.0805	-2.56***	-0.0335	-0.86	0.0146	0.28	-0.0665	-1.56
Small	0.1371	2.34**	0.0357	0.49	0.0591	0.64	0.0393	0.49
Positive	-0.049	-1.45	-0.0113	-0.27	0.0201	0.36	-0.0688	-1.51
Negative	0.0053	0.108	-0.0323	-0.53	0.0369	0.45	0.0133	0.19
CPI (72 announcements)								
Constant	0.00002	0.02	-0.0001	-0.11	0.00004	0.03	-0.0002	-0.24
CPI	-0.0085	-0.35	-0.0131	-0.45	-0.0014	-0.04	-0.0178	-0.55
Large	-0.0192	-0.74	-0.0206	-0.64	-0.0005	-0.01	-0.0287	-0.824
Small	0.0505	0.83	0.0277	0.37	-0.0065	-0.06	0.0425	0.52
Positive	0.0082	0.17	0.0294	0.5	-0.0026	-0.03	-0.0637	-1
Negative	-0.0143	-0.51	-0.0279	-0.82	-0.0010	-0.02	-0.0018	-0.05
PPI (72 announcements)								
Constant	0.00002	0.03	0.0001	-0.09	0.00004	0.03	-0.0002	-0.23
PPI	-0.0041	-0.44	0.0039	0.336	0.0023	0.15	-0.0089	-0.71
Large	0.0027	0.25	0.0047	0.36	-0.0053	-0.29	-0.0041	-0.29
Small	-0.0278	-1.41	0.0010	0.041	0.0257	0.83	-0.0256	-0.96
Positive	-0.0196	-1.44	-0.0228	-1.36	0.0027	0.13	-0.0152	-0.83
Negative	0.0099	0.76	0.0281	1.76*	0.0019	0.084	-0.0033	-0.18
Retail Sales (72 announcements)								
Constant	0.00003	0.04	0.0001	-0.09	0.00004	0.03	-0.0002	-0.21
Retail Sales	-0.0044	-0.79	-0.0002	-0.03	0.0016	0.18	-0.0103	-1.39
Large	-0.0015	-0.25	0.0015	0.205	0.0017	0.18	-0.0090	-1.11
Small	-0.0181	-1.38	-0.0083	-0.51	0.0009	0.04	-0.0162	-0.91
Positive	-0.0066	-1.05	-0.0043	-0.55	-0.0017	-0.17	-0.0083	-0.98
Negative	0.0029	0.25	0.0134	0.95	0.0122	0.67	-0.0167	-1.08
Durable Goods (72 announcements)								
Constant	0.00001	0.01	-0.0001	-0.12	0.00004	0.03	-0.0002	-0.23
Durable Goods	0.0020	1.56	0.0032	2.04**	0.0000	0.01	0.0008	0.45
Large	0.0020	1.47	0.0032	1.85*	-0.0015	-0.68	0.0025	1.35
Small	0.0016	0.53	0.0031	0.84	0.0069	1.51	-0.0073	-1.83*
Positive	0.0015	0.91	0.0010	0.50	-0.0035	-1.38	-0.0008	-0.34
Negative	0.0027	1.33	0.0064	2.63***	0.0053	1.72*	0.0031	1.14
Construction Spending (72 announcements)								
Constant	0.00000	0.01	-0.0001	-0.12	0.00003	0.02	-0.0002	-0.22
Construction Sp.	-0.0006	-1.26	-0.0007	-1.21	-0.0004	-0.52	0.0003	0.44
Large	-0.0006	-1.21	-0.0007	-1.17	-0.0003	-0.41	0.0003	0.45

Small	-0.0064	-0.87	-0.0065	-0.72	-0.0198	-1.74*	-0.0026	-0.26
Positive	0.0017	0.34	0.0017	0.28	0.0194	2.61***	-0.0052	-0.8
Negative	-0.0006	-1.3	-0.0007	-1.24	-0.0006	-0.79	0.0003	0.52
GDP (71 announcements)								
Constant	0.0001	0.07	0.00002	-0.02	0.00002	0.02	-0.0002	-0.17
GDP	-0.0084	-1.31	-0.0161	-2.03**	0.0043	0.43	-0.0121	-1.39
Large	-0.0053	-0.75	-0.0157	-1.8*	0.0155	1.43	-0.0075	-0.79
Small	-0.0234	-1.5	-0.0182	-0.95	-0.0507	-2.1**	-0.0341	-1.63*
Positive	-0.0229	-2.78***	-0.0223	-2.2**	0.0055	0.42	-0.0231	-2.07**
Negative	0.0145	1.39	-0.0062	-0.48	0.0026	0.16	0.0053	0.37
Current Account (72 announcements)								
Constant	0.00003	0.04	0.0001	-0.09	0.0001	0.04	-0.0002	-0.23
Current Account	0.1786	0.99	-0.0680	-0.31	0.1549	0.55	-0.1555	-0.29
Large	0.0490	0.24	-0.0364	-0.14	0.2190	0.71	0.0889	0.327
Small	0.6747	1.71*	-0.1888	-0.39	-0.1141	-0.18	-0.1555	-0.29
Positive	0.2180	0.69	-0.1677	-0.43	0.2491	0.503	-0.0146	-0.03
Negative	0.1592	0.73	-0.0189	-0.07	0.1111	0.33	0.0643	0.217
Auto Sales (71 announcements)								
Constant	0.00002	0.02	0.0001	-0.09	0.00004	0.03	-0.0002	-0.24
Auto Sales	0.0230	0.38	0.0027	0.03	0.0694	0.71	0.0495	0.61
Large	0.0415	0.6	0.0356	0.42	0.1161	1.02	0.0413	0.44
Small	-0.0364	-0.29	-0.1034	-0.67	-0.0680	-0.34	0.0758	0.45
Positive	0.0561	0.66	0.0341	0.33	0.1864	1.3	-0.1531	-1.35
Negative	-0.0131	-0.15	-0.0316	-0.29	-0.0340	-0.25	0.2709	2.29**
Consumer Confidence (72 announcements)								
Constant	0.00002	0.02	-0.0001	-0.11	0.0001	0.06	-0.0003	-0.25
Consumer Conf.	-0.0260	-0.35	-0.1063	-1.17	0.2300	2.03**	-0.1477	-1.48
Large	-0.0673	-0.83	-0.1160	-1.17	0.1750	1.41	-0.1368	-1.26
Small	-0.0065	-0.87	-0.0065	-0.72	-0.0198	-1.74*	-0.0026	-0.26
Positive	-0.0746	-0.65	-0.1435	-1.02	0.2317	1.32	-0.0730	-0.47
Negative	0.0096	0.09	-0.0789	-0.65	0.2287	1.52	-0.2025	-1.54
Industrial Production (72 announcements)								
Constant	0.00003	0.04	0.0001	-0.09	0.0001	0.04	-0.0002	-0.23
Industrial Prod.	-0.0326	-2.46***	0.0128	0.78	-0.0290	-1.4	-0.0077	-0.43
Large	-0.0341	-2.25**	0.0230	1.23	-0.0131	-0.56	-0.0048	-0.23
Small	-0.0275	-1	-0.0209	-0.62	-0.0834	-1.92*	-0.0171	-0.46
Positive	-0.0377	-2.09**	-0.0010	-0.04	-0.0584	-2.08**	0.0010	0.04
Negative	-0.0264	-1.33	0.0294	1.2	0.0068	0.22	-0.0181	-0.67
Leading Indicators (72 announcements)								
Constant	0.00003	0.04	0.0001	-0.07	0.0001	0.08	-0.0003	-0.32
Leading Ind.	-0.0053	-0.20	-0.0129	-0.39	-0.0379	-0.93	0.0675	1.91*
Large	-0.0058	-0.21	0.0102	0.28	-0.0537	-1.21	0.0693	1.82*
Small	-0.0020	-0.03	-0.1477	-1.73*	0.0587	0.54	0.0562	0.6
Positive	-0.0229	-0.73	0.0111	0.29	-0.0128	-0.27	0.0081	0.19
Negative	0.0396	0.79	-0.0798	-1.25	-0.1096	-1.35	0.2185	3.27***
Non-Farm Payrolls (72 announcements)								
Constant	0.00002	-0.02	0.0001	-0.06	0.0001	0.08	-0.0002	-0.22
Non-farm Payrolls	-0.0039	-1.07	0.0029	0.64	0.0042	0.75	0.0005	0.10
Large	-0.0022	-0.56	0.0047	0.97	0.0047	0.77	0.0020	0.36
Small	-0.0136	-1.42	-0.0079	-0.67	0.0014	0.092	-0.0080	-0.62
Positive	-0.0260	-2.74***	-0.0103	-0.88	-0.0047	-0.32	-0.0122	-0.95

Negative	0.0000	0.01	0.0052	1.07	0.0058	0.95	0.0027	0.52
			Housing Starts (72 announcements)					
Constant	0.00004	0.04	0.0001	-0.09	0.00002	-0.02	-0.0002	-0.24
Housing Starts	-0.0292	-0.35	-0.0041	-0.04	0.1385	1.05	0.0208	0.18
Large	-0.1254	-1.30	-0.0664	-0.55	0.1046	0.68	0.0111	0.08
Small	0.2598	1.55	0.1831	0.88	0.2372	0.91	0.0501	0.22
Positive	-0.1183	-1.16	-0.0828	-0.66	0.0822	0.51	-0.0251	-0.18
Negative	0.1618	1.08	0.1645	0.89	0.2541	1.09	0.1192	0.589

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

Large – impact of news with large (more than one standard deviation from the mean) surprise element
Small – impact of news with small (less than one standard deviation from the mean) surprise element
Positive – impact of news with positive (where realized value is greater than expected value) surprise element
Negative – impact of news with small (where realized value is less than expected value) surprise element

Positive surprises of Retail Sales, Durable Goods, Construction Spending, GDP, Auto Sales, Consumer Confidence, Industrial Production, Leading Indicators and Housing Starts as well as negative surprises of Trade Balance, Unemployment, CPI, PPI, Current Account and Non Farm Payrolls are considered as favorable news

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + (1) \sum \alpha_i S_{i,k,t} + (2) \sum \beta_i S(L)_{i,k,t} + (2) \sum \gamma_i S(S)_{i,k,t} + (3) \sum \delta_i S(P)_{i,k,t} + (3) \sum \eta_i S(N)_{i,k,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;
$S_{i,k,t}$ is the surprise component of the macro announcement *k* on day *t*, and is equal to ln (A/E) or A-F[17], where A is the realized value while E is the expected value
$S(L)_{ik,t}$ *and* $S(S)_{ik,t}$ are the surprise components of the macro announcement *k* with the large (more than one standard deviation from the mean) and small (less than one standard deviation from the mean) surprise element on day *t*
$S(P)_{ik,t}$ *and* $S(N)_{ik,t}$ are the surprise components of the macro announcement *k* with the positive (where realized value A is greater than expected value E) and negative (where realized value A is less than expected value E) surprise element on day *t*
ε_{it} is the error term

[17] ln (A/E) is estimated for most indicators, while A-F is estimated only when the use of ln(A/E) would be misleading (e.g. when both realized and expected figures are negative and the realized figure is smaller than expected, ln (A/E) would be positive)

CHAPTER 6. SEASONALITY PATTERNS IN THE FX RETURN SERIES (EMPIRICIAL)

The purpose of this chapter is to examine the seasonality patterns and anomalies in the FX return series. Given that most of the studies on the seasonality patterns focused on the equity market, we contribute to the existing literature by focusing on the FX return anomalies. We hypothesize that the seasonality in the equity markets should drive calendar patterns in the FX markets. For example, a tax loss selling, which explains January effect, turn of the year effect and the monthly patterns (eg November[1] in USA and April in UK) is likely to create capital flows and therefore result in the FX seasonality. The tendency of many FX transactions to occur during particular periods (eg financial statement disclosures, payment of the municipal and corporate debt) could explain some intra-monthly and quarterly patterns.

We find evidence of the day of the week effect in the FX return series, confirming the findings of Aydogan and Booth (1999) and Yamori and Kurihara (2004) for the currency markets. However, we find evidence of not only negative Friday returns[2], but also evidence of positive and significant Thursday returns, which is a contribution to the existing literature on the FX intraweek patterns. After finding evidence of a significant relation between FX return series and US macroeconomic announcements, we explain positive and significant Thursday and negative Friday returns by the invoicing patterns in the world trade and the response of speculator and dealers to the major scheduled news announcements.

We contribute to the existing literature on the monthly seasonalities, by (i) finding that the January effect documented for the equity and bond markets (Rozeff and Kinney, 1976 and Jones et. al, 1987) also exists in the currency markets and (ii) confirming that this effect tends to strengthen in the "bad" years characterized by low GDP growth rate, and

[1] Tax year end for the mutual funds in the US
[2] which is explained by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) and has already been documented for the FX (Cornet et. al, 1995) and equity (Jaffe and Westerfield, 1985 and Ball and Bowers, 1986) markets

tends to weaken in the "good" years characterized by high GDP growth rate[3]. We find evidence of the negative and statistically significant November returns, which is consistent with the hypothesis that the tax loss selling explains monthly seasonality patterns[4]. Finally, as another contribution, we find evidence of stronger monthly anomalies in 1994-1998 period compared to 1999-2003, and explain this by the fact that the markets have adjusted for the calendar anomalies as the monthly seasonalities became well-known phenomenon and the tax shelters removed any reason for selling in order to create a tax loss. We conclude that although there is evidence of the month of a year effect in the FX markets, the effect is not persistent, and has not been significantly affected by the introduction of euro.

We find evidence of a turn of the year effect in the FX market, confirming the findings of Ariel (1987), Lakonishok and Schmidt (1988) and Howe and Wood (1993) reported for the equity markets. As a contribution, we find evidence in support of the hypothesis that the effect has become more pronounced in post euro period due to a higher sensitivity of the exchange rates to the calendar anomalies in post euro period. We find that the average daily return in the last three business days in December is positive and statistically significant, while the average daily return in the first three business days in January is negative, but statistically less significant.

Finally, we study the holiday effect, and find evidence of the positive pre holiday and negative post holiday average return. Although we confirm the findings of the studies on the pre holiday effect (Aydogan and Booth, 1998 for the FX and Lakonishok and Schmidt, 1988 and Wood, 1994 for the stock market), only for USD/EUR we obtain statistically significant results. This is an evidence of a weakening pre holiday effect, which has already been documented in the equity (Tan and Tat, 1998) and currency markets (Liano, 1995). We do not find any evidence in support of the theory proposed by Lakonishok and Schmidt (1988), according to which, the behavior of the equity prices

[3] We recognize limitations of our study, which takes into account US GDP only. Given that the FX rates could be impacted by the relative GDP growth rates in two countries (eg USA and EU, Japan), the study could be extended by including the relative GDP growth rates in two countries

[4] Although Bhabra et. al (1999) reports November effect in the US stock market after 1986, when the Tax Reform Act of 1986 changed the tax year-end for all mutual funds to realize capital gains and losses to October 31st from December 31st, our study is the first to link November effect in the FX market to the tax loss selling.

prior to holidays should be similar to that on Fridays (just before a weekend) and the behavior of the prices after holidays should be similar to that on Mondays[5]. Contributing to the existing literature, we explain the results by the fundamental difference between stock and FX market structures and by the fact that there is less opportunity in the FX market for informed trader to take advantage of uninformed traders. We consider this as an evidence supporting the hypothesis that the calendar seasonalities in the FX market are different from those in the equity market due to the different market structures. We find that the holiday effect tends to weaken after 1999, and explain this by the increased interdependence among geographic markets, which reduces a need to flatten positions prior to holidays. Finally, we study the impact of non-US holidays in the FX market, and contribute to the existing literature on the FX holiday effect, by concluding that the FX holiday effect is mainly driven by the US rather than European, Japanese and UK holidays.

Section 6.1 examines day of the week effect in the return series. Section 6.2 and 6.3 study monthly and intra-monthly patterns in the FX return series, respectively. Section 6.4 focuses on the turn of the year effect, while section 6.5 examines the holiday effect. Finally, section 6.5 concludes.

[5] the theory is explain by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990).

6.1 Day of the Week Effect in the FX Returns

The results of the regression equation 4-4 are presented in Table 6-1[6]. Monday effect indicated by low Monday returns is detected only for USD/EUR, but the regression coefficients are not significant at 10% significance level. Given that USD/EUR returns on days of the week apart from Monday are positive, negative Mondays returns indicate the existence of the weekend effect. USD/GBP and USD/CHF generate negative returns on Mondays, but for USD/GBP, Monday return is the second lowest after Friday return, and for USD/CHF, Monday return is the third lowest after Friday and Wednesday returns. However, there are patterns that all exchange rates follow. For example, on Fridays, all currency pairs, except USD/EUR generate negative return that is lower than return generated on any other day of the week. While Friday is the day of the week, when exchange rates generate negative return, Thursday is characterized by positive and statistically significant returns. For all exchange rates, Thursday is the weekday with the highest rate of return[7], followed by Tuesday for three exchange rates (all but USD/GBP).

The results suggest that there is some, albeit weak evidence of the day of the week effect in the FX market, which is in line with the hypothesis 9 and consistent with Aydogan and Booth (1999) and Yamori and Kurihara (2004), who reported day of the week effect in the FX market for the 1980s. Although Yamori and Kurihara (2004) suggested that the day of the week effect observed in the currency markets in the 1980s disappeared in 1990s, we conclude that the anomaly weakened, but did not disappear completely.

Although, the exchange rate of USD/EUR generate the lowest return on Monday, none of the Monday coefficients is statistically significant that is not consistent with the weekend effect in the stock markets. Low Monday return detected in the equity market

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[6] The regression coefficient indicating the relation between contemporaneous and lagged volatility changes is negative for all exchange rates, and significant at 1% significance level for USD/GBP and USD/CHF in the 10 year sample period, and at 10% significance level for all exchange rates in the later five year sub sample. This result implies mean reversion in implied volatilities and confirm the existing findings on the equity market and FX markets (Ederington and Lee, 1996 and Davidson et. al, 2001).

[7] The hypothesis that Thursday return is different from Monday return is rejected 90% confidence level for USD/CHF and at 95% for USD/GBP.

have been explained by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), who argued that due to the equity markets being closed for a weekend, the information advantage for the informed trader is greatest on Monday opening. Since the FX is a 24 hour market, there is less opportunity in the FX market for informed trader to take advantage of uninformed traders, which explains why we do not see Monday effect, documented in other security markets. This provides evidence in support of the hypothesis 1 and 9, suggesting that the intraweek seasonality patterns in the FX market are different from those in the equity market due to the different market structures.

We try to explain the day of the week anomaly by the macro news announcements in section 6.1.1. In section 6.1.2, we compare the day of the week effect in pre and post euro periods. Finally, in section 6.1.4, we discuss few robustness checks.

6.1.1. Day of the Week Effect in the FX Returns & News Announcements

Table 6-2 presents the results of the regression equation 4-6, whose purpose is to detect whether there is a link between the day of the week effect and the release of the scheduled news announcements. Although most of the coefficients are still insignificant, which implies that the day of the week effect is relatively weak, four coefficients denoting the announcement days are statistically significant at 90% confidence level, while only one coefficient denoting non-announcement days is significant at 90% confidence level. Tuesday and Thursday returns on the announcement days are positive and statistically significant for three out of four exchange rates, while only one coefficient is statistically significant on non-announcement days. These results provide evidence in support of the hypothesis 10, indicating that the US news announcements do explain day of the week effect, at least to some extent. These findings is the contribution to the existing literature on the currency intraweek patterns, and contradicts Yamori and Kurihara (2004), who suggested that the currency anomalies are not driven by the US settlement mechanism or US news release timing, after finding the evidence of the day of the week effect only for a few out of 29 currencies.

Given the obvious link between the news announcements and the currency return anomalies, the day of the week effect, indicated by the positive and significant Thursday and negative Friday returns can be explained by the invoicing patterns in the world trade and actions of speculator and dealers prior to the major regularly scheduled news announcements (Cornet et. al, 1995). As indicated by Grassman (1973), the international transactions tend to be denominated and invoiced in the exporting firm's currency. If this is true, firms in every country will likely be net buyers of foreign currency and net sellers of the home currency. This implies that European and Japanese firms are net buyers of dollars while firms in the U.S. are net buyers of foreign currency (e.g. EUR, JPY, GBP, CHF). This has been shown by Cornet et. al (1995), who provided evidence that the firms in three European countries (UK, Germany and Switzerland) are net buyers of USD and the firms in the US are net buyers of foreign currency. In US, US importers of foreign currency-invoiced goods hedge their natural exchange rate exposure by purchasing foreign currency during the week, and US banks provide liquidity to the market, by taking the opposite side of these transactions and therefore accumulate net long positions in the US dollar. In Europe and Asia, importers of USD-invoiced goods hedge their exchange rate exposure by purchasing US dollar during the week, while foreign banks take opposite positions side of these transactions and therefore accumulate net long positions in the foreign currencies. A large amount of the US macroeconomic announcements is released early late Thursday afternoons after U.S. markets have closed (e.g., money supply) and on Friday mornings (e.g., unemployment, producer price index, capacity utilization) (Harvey and Huang, 1991), causing increased volatility in the currency markets. Since accumulation of the long positions in the domestic currency places US and non-US banks in an exposed position, banks attempt to flatten their positions prior to the release of the important macroeconomic data. US banks would flatten their positions, by selling USD inventories at the end of the business day on Thursday in order not be exposed to the macroeconomic announcements scheduled for late US Thursday and early US Friday. The resulting depreciation of USD explains positive and statistically significant Thursday coefficients reported in this study. European and Japanese banks would have an opportunity to flatten their positions on Friday prior to the opening of US market, when the majority of the US macroeconomic data is announced. By selling the inventories of foreign currency, foreign banks would drive foreign currency prices down, which explain negative Friday coefficients. The fact that the Friday coefficient is statistically significant for USD/JPY only could be explained by the relative higher importance of Japan-US trading relationships, compared to the one between USA and European countries[8].

Negative Friday returns could also be explained by the private information hypothesis of Admati and Pfeiderer (1988) and Foster and Viswanathan (1990). According to Foster and Viswanathan (1990), the weekend closing of most financial markets causes the information advantage for informed traders on Monday opening that explains the well-documented negative Monday returns for equities and other assets. In the currency markets, where in spite of the continuous trading, active trading occurs during the opening hours of the large market centres in the diverse time zones of London, Tokyo and New York, there are two periods during which significant deviation from the twenty-four hour trading environment occurs. First of all, after US markets close down on Friday, the active FX trading resumes as Far Eastern markets begin trading on Monday after a long weekend shutdown. The second main deviation occurs on Friday when European banks close at noon (6:00 am CT) and US banks open at 7:20 am CT, 1 hour 20 minutes later. Although, the use of the daily data does not allow us to directly test the private information hypothesis in the FX markets, it is possible that the negative Friday returns could be explained by the currency markets being relatively inactive prior to the US close and the behavior of the informed liquidity traders on the Friday opening in the US.

6.1.2. Pre and Post Euro Periods

Table 6-1 reports the day of the week effect regression coefficients for the sample periods of 1994-1999 and 1999-2003, while Figure 6-1 and 6-2 graphically presents daily rates of return by the day of the week. Although, we reported statistically insignificant, though negative returns on Monday and positive returns on Tuesday for the entire ten-year sample period, we report positive Monday and negative Tuesday returns for three exchange rates, when the sample period of 1994-1999 only is considered. Positive Monday returns could be interpreted as an evidence of the reversed weekend effect, which was

[8] As shown by Cornet et. al (1995), more than 60% of the Japanese exports and more than 90% of the total imports are invoiced in the USD. This numbers are significantly greater than the equivalent ratios reported for the European countries (range between 7.1% and 33.1%).

reported for the stock market for the period of late 1980s and early 1990s (Brusa et al., 2000, 2003), however, the coefficients are not statistically significant even at 10% significance level to make such inference. Tuesday return is the lowest for USD/EUR and second lowest for USD/GBP and USD/CHF in the first five-year sub-sample. In the pre euro sample, FX rates tend to fall on Friday, and rise on Thursday.

The results reported for the post euro period suggests that negative Monday returns reported for ten-year sample period are driven by 1999-2003 results. Only USD/JPY generate positive rate of return on Mondays, while USD/EUR and USD/CHF generate the lowest return, and USD/GBP generates the second lowest rate of return in the period of 1999-2003. Negative Monday return has been reported for the stock markets[9], and was explained by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990). Increased trading on Monday causes significant fluctuation in the securities prices, resulting in the seasonality patterns. Although we report similar negative Monday coefficients in the post euro sample, none of the coefficients is statistically significant at 10% confidence level. As indicated above, the insignificant Monday coefficients are due to the 24 hour nature of the FX market, which implies that there is less opportunity in the FX market for informed trader to take advantage of uninformed traders. However, only limited trading takes place outside working hours of the major trading centres (e.g. London, New York, Tokyo), so we do see some evidence of the weekend effect, indicated by negative, though statistically insignificant Monday returns. Besides, since the early Monday morning activity in East Asian markets coincide with Sunday nights in GMT, the impact of the private information based trading is spread over Sunday and Monday. Monday effect in currencies is likely to be significant in the opening prices in Far East trading, as these are the first markets in the world to begin trading on Monday after a long weekend shutdown (partly explaining why the Monday coefficients are not significant).

Tuesday and Wednesday coefficients are positive and statistically more significant in the sample period of 1999-2003 than in 1994-1999. We report positive Wednesday returns for all exchange rates, however none of the coefficients is statistically significant at

[9] French (1980), Gibbons and Hess (1981), Lakonishok and Levi (1982), Keim and Stambaugh (1984), Jaffe and Westerfield (1985), Harris (1986), and Ball and Bowers (1986)

10% significance level (consistent with the findings of Aydogan and Booth, 1999 and Yamori and Kurihara, 2004). The results reported for Monday, Tuesday and Wednesday provide some, albeit weak evidence in support of the hypothesis 2, which suggests that seasonality patterns are more pronounced in the post euro period. This could be expected since the currency markets have become more volatile following the introduction of euro (Heaney and Swieringa, 2003), resulting in more pronounced seasonality patterns. Besides, the finding that the Monday effect reappeared after the introduction of Euro could be explained by the hypothesis that the market direction explains the seasonality patterns in the asset return series (Fishe et. al, 1993 and Arsad and Coutts, 1997). Steeley (2001) provided evidence that the weekend effect had disappeared in the UK stock market in 1990s, but found evidence of the significant seasonality patterns when negative returns, denoting market fall, only are considered. Since USD appreciated in 1994-1999 time period, but depreciated during 1999-2003, the Monday effect is more visible in the later period.

Although we report statistically more significant results for Monday, Tuesday and Wednesday returns in the sample period of 1999-2003, Thursday and Friday coefficients are less significant in 1999-2003. Nevertheless, there is still tendency for the FX prices to rise on Thursdays and fall on Fridays. Thursday coefficient is positive for all currency pairs, but the results are significant only for USD/GBP at 5% significance level. The FX rate of USD/EUR generates negative rate of return on Thursday, which is surprising, given the tendency of the FX markets to rise on Thursdays. Negative Thursday return could be explained by the fact that the selling pressure on USD imposed by the banks, which attempt to reduce their long USD positions prior to the release of the important macroeconomic data is offset by the pressure on EUR, resulting from the interest rate announcements. In 2000 the US Federal Bank (Fed) dropped Fed rate several times creating an expectation of similar cuts in Europe. Since the European Central Bank (ECB) makes interest rates announcements on Thursdays, a pressure on EUR caused by the series of the unfavorable announcements tends to offset a fall in USD, resulting in the negative Thursday returns. This explanation is consistent with Yamori and Kurihara (2004), who argued that the daily anomalies in the currency markets are due to not only US settlement mechanism or US news releases, but also to some European-specific factors. Another explanation for a fading Thursday and Friday effect in the currency market is that the seasonality patterns tend to fade out, as traders continue to try to exploit a documented and known anomaly.

The results suggest that Friday returns are still negative for three FX rates in 1999-2003 period, although the coefficients are less statistically significant. This could be explained by the timing of the main US macroeconomic news releases and the economic slowdown in US in post 1999 period, indicated by increasing inflation, falling consumer confidence, increasing unemployment and slower GDP growth. The downward pressure on USD caused by US unemployment, producer price index, and capacity utilization announcements on Friday tend to partially offset USD appreciation driven by non-US dealers and speculators selling foreign currencies. As the result, we observe less significant Friday coefficients in 1999-2003 sample period. Less significant Thursday and Friday coefficients reported for 1999-2003 period leads us to reject hypothesis 2, according to which, seasonality patterns are more pronounced in the post euro period.

6.1.3. Robustness Checks

As the robustness test, we run another regression model, based on the model introduced by Connoly (1989) and later employed by Chang et. al (1993) and Brusa et al. (2003, 2003). We test whether Thursday (rather than Monday) returns are significantly different from the returns generated on the remaining days of the week and conclude that the results are robust to the choice of the regression model.

6.2. Monthly Patterns in the FX Returns

We examine January effect in section 6.2.1. In section 6.2.2, we study the monthly patterns, by focusing on the monthly returns in each month of a year. Finally, in section 6.2.3, we highlight our contributions to the existing literature on the FX monthly patterns.

6.2.1. January Effect

Table 6-4 shows the results of the regression model 4-8, indicating that the January returns are negative for all exchange rates. The results are consistent with the hypothesis 11, while the hypothesis that January returns are not significantly different from the returns generated during the remaining months of a year can be rejected in favour of the hypothesis 12, for all currency pairs, apart from USD/JPY, at 10% significance level. The results clearly indicate the existence of the January effect. For USD/GBP and USD/EUR, the January effect is observed in pre euro period, but the coefficient are statistically significant in post euro period. In contrast, the results reported for USD/CHF and USD/JPY suggest that the January effect did not exist in 1994-1999 period, but appeared after the introduction of euro. Our results confirm that the January effect documented in the equity and bond markets (Rozeff and Kinney, 1976, Schultz, 1985 and Jones, Pearce and Wilson, 1987) also exists in the currency markets.

January effect can be explained by the invoicing patterns in the world trade and actions of speculators and dealers prior to the holidays, which tend to explain FX day of the week effect. Since the international transactions tend to be denominated and invoiced in the exporting firm's currency (Grassman, 1973), the US firms are likely to be net buyers of foreign currency and net sellers of the home currency (USD). Dealers and speculators in US, which are mainly banks, provide liquidity to the market, by taking the opposite side of the transactions and therefore accumulate net long positions in the US dollar. Dealers prefer to flatten their positions prior to the events, which might cause significant increase in the currency volatility. These events include important news announcement, weekends and holidays, during which the markets are closed, and banks are unable to adjust their position in response to the events that take place while markets are closed. Therefore, the accumulation of the long positions in the domestic currency, places banks in an exposed position prior to the long holidays in the end of December and early January. Dealers flatten their positions prior to the December/January holidays, by selling USD inventories in the end of December and buy USD back in January after the holidays. This would explain positive returns in January and would also suggest that December USD returns should be negative.

Another explanation for the January effect is the tax loss-selling hypothesis, which explains January effect in the US stock market[10]. According to the portfolio adjustment or capital movement theory that explains the relation between stock prices and exchange rate movements, changes in stock prices influence movements in the exchange rates via portfolio adjustments, and specifically inflows and outflows of foreign capital (Tabal, 2006). Upward trend in stock prices results in the inflow of foreign capital, causing currency appreciation. Therefore, consistent with the portfolio adjustment theory, as investors buy the shares in January, the demand for USD increases, causing USD appreciation. As the result, we observe negative January returns in the currency markets, which are significantly different from the return generated during the remaining months of a year.

Finally, Figure 6-3 depicts the dynamic of the January effect or the contribution of the January to the annual rate of return in each year in the period of 1994-2004. In order to understand whether the January effect depends on the macroeconomic conditions and specifically on the conditions of the economy, we use the GDP growth rates as the proxy for "good" and "bad" market years. High GDP growth rates indicate the "good years", while low GDP growth rates indicate the "bad years" (the GDP growth rate[11] tends to increase in the each of the first three years beginning from 1997, and then declines sharply in 2000 reflecting bad macroeconomic conditions in the US economy). In most years, the power ratio is below one, indicating the fact that the January return is below the average

[10] Roll (1983), Reinganum (1983) and Keim (1989) showed that there is a downward pressure on the prices of those stocks, which have declined during the year as investors attempt to realize their losses against their taxable income. After the end of the tax-year, price pressure disappears and the prices reach equilibrium level, causing positive share price returns in January.

[11] Figure 6-4 presents the final US GDP growth rates for each year in 1997-2003 period. Due to the limited data, our analysis in this section is constrained to this period.

return of other months. In five out of ten years, the power ratio for at least one currency pair is above one. The results are consistent with the conclusion that although there is evidence of the January effect, the effect is not persistent. By comparing Figures 9 and 10, we note that for most rates, the power ratio is low in the years of relatively low GDP growth rates and high (closer to one) in the years of high GDP growth rate. As GDP growth rate increases in the years of 1997-1999, the power ratio tends to rise before falling again in the recession years of 2000-2002. The power ratio again increased in 2003 as the result of the increase in the GDP growth rate. Therefore, we can confirm that January effect tends to strengthen in the "bad" years characterized by low GDP growth rate, which create an opportunity to book tax losses and tends to weaken in the "good" years characterized by high GDP growth rate.

6.2.2. Returns by Months of a Year

The results of the regression equation 4-9 are presented in the Table 6-5. It is obvious that in the sample period of 1994-2003, each exchange rate generated the lowest return in January. November is the month with the second lowest return after January, while September and December are the months with the highest rate of return for USD/EUR, USD/GBP and USD/CHF. Positive and statistically significant[12] December returns are consistent with both explanations for the January effect proposed above. According to the tax loss-selling hypothesis, investors sell poor performing stocks in the end of December that would induce a reduction in domestic investors' wealth, leading to a fall in a demand for money and lower interest rates, causing capital outflows that would result in USD depreciation. Besides, if US banks flatten their long USD position before December holidays, which is another explanation for the January effect, December USD returns should be negative and significant.

Negative November returns are consistent with the hypothesis that the tax loss selling explains monthly seasonalities in the currency markets. Bhabra et. al (1999) documented the existence of the November effect in the US stock market, after the passage of the Tax Reform Act of 1986. The Tax Reform Act of 1986 changed the tax year-end for all mutual

[12] at 10% confidence level

funds to realize capital gains and losses to October 31st from December 31st. By requiring mutual fund managers to distribute at least 98% of the realized capital gains income generated during the 12 month period ending October 31st to avoid 4% excise tax, the Act created an incentive for the mutual funds to sell loss-making stocks prior to 31st of October. Since mutual funds are dominant players in the US equity markets, Bhabra et. al (1999) hypothesized that the behavior of the US stock market in November in post 1986 period should be consistent with the January effect. By finding evidence of no November effect prior to 1986, but the significant and positive November returns following 1986, Bhabra et. al (1999) concluded that tax loss selling explains positive US equity returns in November and January. The sale of poorly performing US stocks in November is likely to result in the depreciation of the USD in October and the subsequent appreciation in November. Consistent with this hypothesis, we do observe positive FX returns in October and statistically significant and negative returns in November.

Contrary to the hypothesis that the tax loss selling should cause April USD/GBP returns being positive and statistically significant, none of the exchange rates, including USD/GBP, generates statistically significant returns in April. However, since according to the tax loss selling, investors would be selling UK stocks during the first 5 days in April, it possible that negative GBP returns in the first five days in April offset positive returns during the remainder of the month. In order to check that the behavior of the USD/GBP exchange rate in April is consistent with tax loss selling, we run two more regression models. The first model compares April returns prior to and following the tax year-end, while the second model tests the hypothesis that April returns following the tax year end are not significantly different from the return generated during the remaining days of a year. The results of the regression model, provided in the Table 6-6, imply that USD/GBP returns generated during the first 5 days in April are significantly different from those in the remaining days in April. Besides, average daily return during the first five days in April is negative and significant, while the return generated during the remaining days in April is positive. These results are consistent with the tax loss selling, but the results of the second regression does not allow us to reject the hypothesis that April returns following the tax year end are not significantly different from the return generated during the remaining days of a year. In summary, although, we do find some evidence in support of the tax loss selling, the results suggest that tax loss selling does not fully explain monthly patterns observed in the currency markets. These results are consistent with Hillier and Marshall (2002), who reported results consistent with the tax loss-selling hypothesis, but rejected the hypothesis that the tax loss selling is the sole determinant of the January effect in the equity markets. Therefore, the factors apart from tax loss selling, including invoicing patterns in the world trade and actions of speculators and dealers prior to the holidays, which have already been discussed above, also contribute to the January effect anomaly in the FX market.

Significant positive September returns could be explained by the September effect documented for the US stock market. Siegel (2006) noted that from 1890 through 1994, the Dow Jones industrial average or its predecessor fell in 63 Septembers and rose only in 41. The index rose during 56 percent of the months during the period of study, and in fact September was the only month with a losing record over the 104 years. According to Siegel (2006), the September effect was more pronounced during the last two and a half decades prior to mid 1990s, during which the Dow rose only five times in the month. Negative September equity returns could be explained by the fact that many hedge funds book profits before the fiscal year end, especially given many mutual funds end their fiscal year in October. We already discussed that good stock market performance in January and November leads to USD appreciation, while poor equity performance in December and October results in USD depreciation. Dornbusch (1975) and Boyer (1977) provided evidence that decreases in stock prices reduce domestic wealth, lowering demand for money and interest rates, inducing capital outflows and currency depreciation. Therefore, poor September equity returns should lead to USD depreciation, resulting in positive and statistically significant September returns reported in our study.

The results reported for 1994-1999 and 1999 – 2003 periods do not suggest that the seasonality patterns are more pronounced in one particular sample period. The January effect is significant for USD/EUR and USD/GBP in pre euro, but is more significant for USD/CHF and USD/JPY in post euro period. Positive December, September and June returns are statistically more significant in 1999-2003 period compared to 1994-1999, while November effect is much more pronounced in 1994-1999 sample period for all exchange rates, apart from USD/GBP. Although, for December, June, September and partially for the January returns, we do find evidence in support of the hypothesis 2, we conclude that the January effect is not persistent and reject the hypothesis for some monthly anomalies, such as the November effect. The results are consistent with the findings of Balaban (1995) and Hillier and Marshal (2002), who also found evidence of the monthly seasonalities in the equity markets, but concluded that the effect is not persistent. This could be explained by the fact that as the monthly seasonalities became well known phenomenon, the markets have adjusted for the effects. Besides, since tax loss selling is the main explanation for the majority of the anomalies, the tax shelters, which have become popular in the recent years, removed any reason for selling in order to create a tax loss.

6.2.3. Contributions

By conducting one of the first studies on the FX monthly seasonalities, we contribute to the existing literature that is limited to the stock markets, by concluding that the January effect also exists in the FX market. By reporting November effect, we provide evidence of the tax loss-selling hypothesis at least partially explaining the monthly seasonalities. We also discuss additional factors, such as the timing of disclosure in the financial statements, the portfolio rebalancing by investors, the invoicing patterns in the world trade and actions of speculators and dealers prior to the holidays, which contribute to the monthly seasonalities in the currency markets. Finally, we conclude that although there is evidence of the January effect in the FX markets, the effect is not persistent, and has not been significantly affected by the introduction of euro.

6.3 Intra-Monthly Patterns in the FX Returns

We hypothesize that the intra-monthly patterns in the equity markets should drive calendar patterns in the FX markets. Possible explanations for the equity intra-monthly patterns are dividend effect, tax loss selling and news announcements concentrated in one part of the month. For example, a tax loss selling is likely to create capital flows and therefore result in the FX seasonality. Because of the capital flows, higher demand for stock imply higher demand for USD, and therefore lower foreign currency returns in terms of USD in the first half of a month, compared to the second half. Consistent with the existing literature on the FX (Aydogan and Booth, 1999) and equities (Penman, 1987 and Stewart, 1987), we expect to find evidence of the positive return generated in the beginning of a month and negative return generated in the final days of a month. Given that substantial payments in the US economy (e.g. salaries and debt interest) are made in the end of a month, we expect to find an evidence of a statistically significant difference between implied volatility changes around a turn of a month and during the remainder of a month (consistent with Martikainen et. al, 1995). We examine first half of the month effect in section 6.3.1. In section 6.3.2, we study the turn of the month effect, and in section 6.3.3, we conduct some robustness checks.

6.3.1. First Half of the Month Effect

The results of the regression model 4-10 are presented in Table 6-7, while Figure 6-5 graphically reports average daily return for the first and second halves of a month. For two exchange rates (USD/GBP[13] and USD/CHF), the average rate of return during the first half of a month is negative and lower than the return generated in the second half of a month (consistent with the existing literature on the stock market). The results reported for the entire ten-year sample period suggest that there is no evidence of the first half of a month effect in the currency markets, implying that the pattern has either never existed or faded as markets incorporated knowledge of the observed patterns in the exchange rates (as suggested by Ariel, 1987 for the equity markets).

[13] Coefficients are statistically significant for USD/GBP only

In the pre euro period of 1994-1999, the US dollar tends to generate higher return in the first half than in a second half of a month, though the results are again significant for USD/GBP only. The regression estimates reported for 1999-2003 period suggest that the introduction of EUR in 1999 results in the diminishing of this effect. This phenomenon could be due to the outliers, which implies that the results may simply be the product of the extensive data mining. Another explanation is that the intra monthly patterns identified through 1980s and 1990s have become a public knowledge, and since the market responds efficiently by trading them out of existence, these patterns faded in the recent years as markets incorporated knowledge of the anomalies into the currency markets.

6.3.2. Turn of the Month Effect

Table 6-8 reports the results of the regression model 4-10 designed to detect turn of the month effect, and to see whether the returns in the last and first three days of each month are different from the return generated during the remaining days of a month. The regression results reported for the ten-year sample period suggest that for three out of four exchange rates, the rate of return is positive in the first three days and negative in the last three days of a month[14] (consistent with Penman's (1987) and Stewart's (1987) findings for the equity and Aydogan and Booth's (1999) findings on the FX market). One explanation for the insignificant regression estimates could be that the turn of the month effect occurs over a different sequence of days (suggested by Ziemba, 1989 for the Japanese stock market).

A weakened turn of the month effect contradicts the findings on the equity markets and could be explained by the FX markets being more efficient compared to the stock market, and therefore displaying weaker calendar patterns. Another explanation could be the fading of the seasonality patterns over time. After studying the calendar anomalies in the daily stock indices of 18 countries, Agrawal and Tandon (1994) found evidence of the fading turn of the month effect, with 11 countries showing the effect in the 1970s and only seven still showing the turn of the month effect in the decade of the 1980s.

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[14] None of the regression coefficients is statistically significant.

Although no evidence of the turn of the month effect is reported for the pre euro sample, the average daily return during the first three days of a month in the sample period of 1999-2003 is significantly different from the return generated during the remaining days of a month for USD/EUR and USD/GBP. The results are consistent with the hypothesis 2, which suggests that the anomalies have become more pronounced after 1999, due to increased currency market volatility (Heaney and Swieringa, 2003) and depreciating USD[15].

6.3.3. Robustness Check

In order to test the robustness of the regression results to the use of two dummy variables instead of one, we run the regression using only one dummy variable that takes the value of one when the day is either the last or the first three days of a month and zero otherwise (as suggested by Lakonishok and Smidt, 1988 and Ogden, 1990). None of the regression coefficients reported in Table 6-9 is significant, suggesting that the return generated in the last and first three days of a month is not significantly different from the return generated during the non-turn of the month days. This implies that our results are robust to the choice of the OLS regression model.

[15]The markets are more sensitive to the calendar anomalies in a declining rather than a rising market (Fishe et. al, 1993, Arsad and Coutts, 1997 and Steeley, 2001).

6.4 Turn of the Year Effect in the FX Returns

As Table 6-10 shows and consistent with the existing literature on the equity markets (Lakonishok and Smidt, 1984), the average return generated in non turn of the year days are positive, but statistically insignificant. The difference between the average daily return during the first and last three business days of a year and average return for the remainder of a year is positive for three exchange rates[16], but is statistically significant at 10% significance level for USD/EUR only. In general, the reported results support the hypothesis 15 and confirm the findings of Ariel (1987) and Howe and Wood (1993) for the equity markets. We try to explain turn of the year effect by a tax loss selling, which creates capital flows, driving calendar patterns in the FX market.

None of the regression estimates for 1994-1998 period is statistically significant, while three out of four exchange rates have coefficients significant at 90% confidence level. These results are consistent with the hypothesis 2, and could be explained by the increased currency market volatility and higher sensitivity of the exchange rates to the calendar anomalies in post euro period characterized by USD depreciation. Another distinctive result is that in the sample period preceding euro, all β_i coefficients are negative, while in the second five-year sample period, three out of four coefficients are positive and statistically significant. This could be explained by the fact that the sales of the loss making stocks by the portfolio managers motivated by tax loss selling is stronger in post euro period, which causes more significant USD depreciation in 1999-2003 sample period. Since, the US stock market underperformed in 1999-2003 period (relative to 1994-1998 period), such behavior of the portfolio managers is expected.

6.4.1. Robustness Checks

As one of the robustness tests, we define turn of the year as the last and first 10 days of a year and run another regression to test whether average daily return in the last and first 10 days of a year is significantly different from the average daily return in the remaining days. As per Table 6-11, β_i regression coefficients, which indicate a difference

[16] all but USD/JPY

between turn of the year return and return for non-turn of the year days, are positive for USD/EUR and USD/GBP, and negative for USD/CHF and USD/JPY. However, none of the regression coefficients is statistically significant even at 10% significance level, which implies that the turn of the year effect disappears when the first and last ten rather than three days of a year are used to define the turn of the year. The results also suggest that contrary to the hypothesis 16, there is no evidence that the market anticipates the turn of the year effect in advance.

We run another regression, where we use two separate dummy variables, one denoting the last three days in December and another denoting the first three days in January. Consistent with the tax loss-selling hypothesis and our explanation of the turn of the year effect, we expect to find positive December and negative January coefficients. The results reported in Table 6-12 indicate that December coefficients are indeed positive, while January coefficients are negative for all exchange rates[17]. Since for three exchange rates December coefficients are more statistically significant than January coefficients, we conclude that the turn of the year effect is mainly caused by positive returns in the last three business days in December. The results are consistent with the findings of Roll (1983), Lakonishok and Schmidt (1984), Howe and Wood (1993), who suggested that December returns are caused by holiday effect (which is also studied in this chapter) and that returns in early January tend to be significantly different from the return during the remainder of a month and a year. One explanation for these results is that portfolio managers sell loss-making stocks to realize capital gains and losses in the last three days in December, resulting in USD depreciation. Negative, but less significant January coefficients are probably due to the fact that it takes longer than three days for USD to return to the previous level. Positive December and negative January returns could also be explained by the traders and portfolio managers flattening their natural long positions in the domestic currency prior to December/January holidays, by selling USD inventories in the end of December and buying USD back in January after the holidays. This phenomenon is known as a holiday effect, and is discussed in the next section.

[17] December coefficients are statistically significant for USD/EUR and USD/CHF, while January coefficient is significant for USD/JPY only. The only exception is the January coefficient reported for USD/EUR, which is statistically insignificant.

6.5 Holiday Effect in the FX Returns

In this chapter, we examine the holiday effect in the FX market. We discuss the impact of US and non US holidays on the FX return series in sections 6.5.1 and 6.5.2, respectively. In section 6.5.3, we conduct a robustness check, by studying a link between holiday and turn of the year effects.

6.5.1. US Holidays

Table 6-13 reports the regression estimates of the equation 4-14, while Figure 6-6 is the graphically presentation of the results. Holiday effect is first tested for US national holidays. As expected and consistent with the hypothesis 18, we do find evidence of the positive pre holiday and negative post holiday returns, which imply that USD depreciates prior to US holidays and appreciates following the holiday. However, none of the coefficient is statistically significant at 10% significance level. Although we find some evidence of a pre holiday effect, confirming the findings of Aydogan and Booth (1998) for the FX and those of Ariel (1990), Howe and Wood (1993) and Wood (1994) for the stock market, the results are not statistically significant and therefore not convincing. This is the confirmation of a weakening pre holiday effect, which has already been documented in the equity (Tan and Tat, 1998) and currency markets (Liano, 1995).

The main explanation for the holiday effect is related to the tendency of the banks to flatten their natural long USD positions prior to the official holidays. The international transactions tend to be denominated and invoiced in the exporting firm's currency (Grassman, 1973), and therefore firms in every country will likely be net buyers of foreign currency and net sellers of the home currency. In US, US importers of foreign currency-invoiced goods hedge their natural exchange rate exposure by purchasing foreign currency during the week, and US banks provide liquidity to the market, by taking the opposite side of these transactions and therefore accumulate net long positions in the US dollar. Since accumulation of the long positions in the USD places banks in an exposed position, banks attempt to flatten their positions prior to the official holidays, by selling USD inventories. The resulting depreciation of USD explains positive pre holiday coefficients reported in this chapter. As banks buy USD back after the markets open following the holiday, USD appreciates, which explains negative and statistically significant post holiday coefficients.

Lakonishok and Schmidt (1988) suggested that the behavior of the equity prices prior to holidays should be similar to that on Fridays (just before a weekend) and the behavior of the prices after holidays should be similar to that on Mondays. We do not find a confirmation of this hypothesis for the currency markets, because of the fundamental difference between stock and FX market structures. First, since large amount of the US macroeconomic data is released on Friday market opening, US banks tend to flatten their natural long USD positions on Thursday, rather than on Friday, which explains why the behavior of the FX prices on pre holiday days are similar to that on Thursdays. On Fridays, European banks also flatten their long positions in the domestic currency, resulting in USD appreciation, which offsets USD depreciation caused by US bank's sales of USD. Therefore, although stock market behaves similarly on Fridays and on the pre holiday days, FX market's behavior prior to holidays is not the same as the behavior prior to weekends. The private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) explains similarity between the behavior of the stock market prices following the holidays and on Mondays. Since the information advantage for the informed traders is greatest after the period of inactivity, such as weekends and holidays, equity returns are statistically significant on Mondays and on post holiday days. Given that the FX market is a 24 hour market, there is less opportunity in the FX market for informed trader to take advantage of uninformed traders, which explains why we do not see a Monday effect. This also explains why the behavior of the currency markets on Mondays is different from that on post holiday days. This provides evidence in support of the hypothesis 1, suggesting that the calendar seasonalities in the FX market are different from those in the equity market due to the different market structures.

As Table 6-13 shows, all of the post holiday coefficients are significant at 5% significance level in the period of 1994-1998, but none of the coefficients in the period of 1999-2003 is statistically significant. One explanation for the stronger calendar effect in the sample period preceding euro is related to the increased interdependence among geographic markets. Although, FX is a 24 hour market, banks prefer to trade within official local trading hours. As markets became more sophisticated, integrated and bounderless in the late 1990s and early years of this decade, the need to trade within the normal working hours diminished, with US banks trading outside the normal US working hours. This reduces a need to flatten positions prior to holidays, because US banks can trade in other markets (e.g. Europe, Far Asia, Middle East), where there is no holiday. This explains why we observe statistically significant post holiday coefficients in 1994-1998 period, but insignificant coefficients in the sample period of 1999-2003.

6.5.2. Non-US Holidays

Table 6-14 suggests that non US pre holiday estimates are positive for all exchange rates, but statistically significant for USD/GBP only. The post holiday coefficients are positive for three out four exchange rates, but statistically significant for USD/EUR only. If the actions of the dealers and banks prior to the official holidays explain the holiday effect, we would expect the depreciation of the foreign currencies against USD prior to non-US holidays and foreign currency appreciation following holidays. However, many of US and non-US holidays tend to coincide, which implies that the impact of US and non-US holidays offset each other, generating ambiguous results.

We run another regression model, where we exclude non-US holidays, which coincide with the US holidays. We exclude Christmas, Boxing Day (St. Stephen's Day in Germany), New Year Day, Easter and Emperor's Birthday in Japan, which coincide with the US December holidays. The results presented in Table 6-15 are consistent with the hypothesis that the actions of the dealers and banks prior to the official holidays causes domestic currency to depreciate prior to the official holiday and appreciate following the holiday. For two exchange rates[18], the pre holiday regression coefficients are negative, while post holiday coefficients are positive for all exchange rates. Nevertheless, none of the regression coefficients is statistically significant at 10% significance level. We contribute to the existing literature on the FX holiday effect, by concluding that the FX holiday effect is mainly driven by the US rather than European, Japanese and UK holidays.

[18] USD/EUR and USD/CHF

6.5.3. Robustness Checks

As a contribution to the existing literature, we study a link between holiday and turn of the year effects. We isolate turn of the year effect by ignoring December holidays to understand whether the holiday effect is caused by the turn of the year effect. We run the regression model 4-14, without taking into account days preceding and following Christmas and New Year Day holidays. If the holiday effect is caused by the turn of the year anomaly, we expect to find insignificant regression coefficients. The results presented in the table 6-16 indicate that although none of the pre holiday regression coefficients is statistically significant, all of the post holiday coefficients are significant at 5% significance level. This suggests that the holiday effect is independent of the turn of the year calendar anomaly.

6.6. Summary

The purpose of this chapter is to study calendar anomalies in the FX return series. The seasonality patterns studied in this chapter are the day of the week effect, month of the year and within-month patterns, the turn of the year and the holiday effect. Although, there is some, though limited literature on the FX day of the week effect (Hilliard and Tucker, 1992, Cornet et. al, 1995 and Aydogan and Booth, 1999), the literature on other seasonality patterns in the FX return series is very limited, providing an opportunity to contribute to the existing literature by studying whether the documented anomalies are unique to the stock market. We hypothesize that the seasonality in the equity markets should drive calendar patterns in the FX markets. For example, a tax loss selling, which explains January effect, turn of the year effect and the monthly patterns (eg November[19] in USA and April in UK) is likely to create capital flows and therefore result in the FX seasonality. The tendency of many FX transactions to occur during particular periods (eg financial statement disclosures, payment of the municipal and corporate debt) could explain some intra-monthly and quarterly patterns. By splitting a sample period into two five-year periods, preceding and following the euro introduction in 1999, we have a unique opportunity to study the impact of the euro introduction on the FX seasonality patterns.

We find evidence of the day of the week effect in the FX return series, confirming the findings of Aydogan and Booth (1999) and Yamori and Kurihara (2004) for the currency markets. However, we find evidence of not only negative Friday returns, which has already been documented for the FX (Cornet et. al, 1995) and equity (Jaffe and Westerfield, 1985 and Ball and Bowers, 1986) markets, but also evidence of positive and significant Thursday returns, which is a contribution to the existing literature on the FX intraweek patterns. After finding evidence of a significant relation between FX return series and US macroeconomic announcements, we explain positive and significant Thursday and negative Friday returns by the invoicing patterns in the world trade and the response of speculator and dealers to the major scheduled news announcements. We also try to explain negative and significant Friday returns by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990). We do not find any

[19] Tax year end for the mutual funds in the US

significant evidence of the Monday effect documented for the equity markets (Jaffe and Westerfield, 1985, Harris, 1986 and Ball and Bowers, 1986) and explained by the private information hypothesis. We conclude that since FX is a 24 hour market, there is less opportunity in the currency market for informed trader to take advantage of uninformed traders, which explains why we do not see Monday effect. We do not find a significant evidence of more pronounced intraweek patterns in 1999-2003 period.

We contribute to the existing literature on the monthly seasonalities, by finding that the January effect documented for the equity and bond markets (Rozeff and Kinney, 1976 and Jones et. al, 1987) also exists in the currency markets. We offer several explanations for the negative and statistically significant January returns, which includes the actions of speculators and dealers prior to the holidays, money managers' inclination to make long-term reassessments of FX trends at the end and beginning of the calendar year, and the tax loss-selling hypothesis, which explains January effect in the US stock market (Roll, 1983 and Tinic and Barone-Adesi, 1983). We contribute to the existing literature by confirming that the January effect tends to strengthen in the "bad" years characterized by low GDP growth rate, and tends to weaken in the "good" years characterized by high GDP growth rate. We find evidence of the negative and statistically significant November returns, which is consistent with the hypothesis that the tax loss selling explains monthly seasonality patterns. Although Bhabra et. al (1999) reports November effect in the US stock market after 1986, when the Tax Reform Act of 1986 changed the tax year-end for all mutual funds to realize capital gains and losses to October 31st from December 31st, our study is the first to link November effect in the FX market to the tax loss selling. By recognizing that the tax and calendar years coincide, which implies that most tests are the joint tests of two year-ends (Hillier and Marshall, 2002), we test tax loss selling hypothesis by hypothesizing that if the tax loss selling explains monthly seasonality patterns, we should observe April effect for USD/GBP, since in the UK, the tax year-end for investors is April 5. We do find some evidence in support of the tax loss-selling hypothesis, but the results suggest that the tax loss selling is not the only factor that explains monthly patterns observed in the currency markets. We explain positive and statistically significant September returns by the September effect in the US stock market, leading to USD depreciation, consistent with the portfolio adjustment / capital movement theory. Finally, we find evidence of stronger monthly anomalies in 1994-1998 period compared to 1999-2003, and explain this by the fact that the markets have adjusted for the calendar anomalies as the monthly seasonalities became well-known phenomenon and the tax shelters removed any reason for selling in order to create a tax loss. We conclude that although there is evidence of the month of a year effect in the FX markets, the effect is not persistent, and has not been significantly affected by the introduction of euro.

We do not find any evidence of the average daily currency returns in the first half of a month being significantly different from the average daily return in the second half of a month. Although, we find evidence of the average daily return being positive in the first three days and negative in the last three days of a month, none of the regression coefficients is significant[20]. This implies that in the currency markets, there is either no turn of the month effect, or as suggested by Ziemba (1989) for Japanese stock market, the turn of the month effect occurs over a different sequence of days. We explain our findings by the fading feature of the turn of the month effect (Agrawal and Tandon, 1994) and the fact that the currency markets are more efficient compared to the stock market, and therefore display weaker calendar patterns.

We find evidence of a turn of the year effect in the FX market, confirming the findings of Ariel (1987), Lakonishok and Schmidt (1988) and Howe and Wood (1993) reported for the equity markets. We find evidence in support of the hypothesis that the effect has become more pronounced in post euro period, and explain this by the increased currency market volatility and higher sensitivity of the exchange rates to the calendar anomalies in post euro period, characterized by USD depreciation. We find that the average daily return in the last three business days in December is positive and statistically significant, while the average daily return in the first three business days in January is negative, but statistically less significant. We explain these results by the fact that the portfolio managers sell loss-making stocks to realize capital gains and losses in the last three days in December, resulting in USD depreciation. Less significant January coefficients could be explained by the fact that it takes longer than three days for USD to return to the previous level.

[20] The coefficients reported for the first three days of a month are statistically significant for the period of 1999-2003 for USD/EUR

Finally, we study the holiday effect, and find evidence of the positive pre holiday and negative post holiday average return. Although we confirm the findings of the studies on the pre holiday effect (Aydogan and Booth, 1998 for the FX and Lakonishok and Schmidt, 1988 and Wood, 1994 for the stock market), only for USD/EUR we obtain statistically significant results. This is an evidence of a weakening pre holiday effect, which has already been documented in the equity (Tan and Tat, 1998) and currency markets (Liano, 1995). We explain the holiday effect mainly by the tendency of the banks to flatten their natural long USD positions prior to the official holidays. We do not find any evidence in support of the theory proposed by Lakonishok and Schmidt (1988), according to which, the behavior of the equity prices prior to holidays should be similar to that on Fridays (just before a weekend) and the behavior of the prices after holidays should be similar to that on Mondays[21]. Contributing to the existing literature, we explain the results by the fundamental difference between stock and FX market structures and by the fact that there is less opportunity in the FX market for informed trader to take advantage of uninformed traders. We consider this as an evidence supporting the hypothesis that the calendar seasonalities in the FX market are different from those in the equity market due to the different market structures. We find that the holiday effect tends to weaken after 1999, and explain this by the increased interdependence among geographic markets, which reduces a need to flatten positions prior to holidays. Finally, we study the impact of non-US holidays in the FX market, and contribute to the existing literature on the FX holiday effect, by concluding that the FX holiday effect is mainly driven by the US rather than European, Japanese and UK holidays.

Throughout our study, we test the robustness of the results to address concerns levied by Connolly (1989), Lindley and Liano (1997), Sullivan et. al (1998) regarding the robustness of anomaly research. We obtain similar results, regardless of whether Monday or Tuesday dummy variables are excluded to avoid the dummy variable trap. For the turn of the year effect, we generate similar results, regardless of whether we define turn of the year as the first or the last 3 or 10 working days of the year. Finally, for the turn of the month effect, defining turn of the month as the last three, first three or six days around the

[21] the theory is explain by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990).

end of the month, generate similar results. These tests confirm that the study results are robust to the choice of the regression model.

Table 6-1. Day of the Week Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0190	-0.71	-0.0040	-0.18	-0.0070	-0.23	0.0050	0.13
TUE	0.0250	0.67	0.0070	-0.21	0.0240	0.53	0.0400	0.85
WED	0.0200	0.53	0.0180	0.59	-0.0010	-0.02	-0.0300	-0.63
THU	0.0510	1.36	0.0690	2.22**	0.0720	1.65*	0.0600	1.29
FRI	0.0230	0.60	-0.0240	-0.77	-0.0240	-0.53	-0.0860	-1.83*

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0044	-0.12	0.0232	0.72	0.0114	0.24	-0.0045	-0.08
TUE	-0.0150	-0.29	-0.0334	-0.75	-0.0288	-0.45	0.0531	0.71
WED	-0.0057	-0.11	-0.0262	-0.58	-0.0147	-0.23	-0.0279	-0.37
THU	0.0764	1.50	0.0375	0.84	0.0807	1.27	0.0880	1.18
FRI	-0.0136	-0.26	-0.0467	-1.05	-0.0613	-0.96	-0.0976	-1.31

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0329	-0.84	-0.0289	-0.94	-0.0243	-0.56	0.0129	0.31
TUE	0.0646	1.17	0.0180	0.41	0.0742	1.23	0.0272	0.74
WED	0.0445	0.80	0.0603	1.40	0.0113	0.18	-0.0306	-0.53
THU	0.0260	0.47	0.0973	2.26**	0.0632	1.04	0.0341	0.59
FRI	0.0575	1.04	-0.0032	-0.07	0.0124	0.20	-0.0733	-1.27

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

The estimation is based on the following model:

$$R_{i,t} = \alpha_0 + \sum\beta_i T_{i,t} + \sum\delta_i W_{i,t} + \sum\gamma_i Th_{i,t} + \sum\eta_i F_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$T_{i,t}$, $W_{i,t}$, $Th_{i,t}$, $F_{i,t}$, $S_{i,t}$, and $S_{i,t}$ are the dummy variables for Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday at time t
ε_{it} is the error term

Table 6-2. Day of the Week Effect with the Announcements

1998-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0320	-0.91	-0.0320	-1.16	-0.0400	-1.010	-0.0320	-0.74
TUE(A)	0.0780	1.35	0.0530	1.15	0.0970	1.5	0.1540	2.19**
WED(A)	0.0440	0.74	0.1030	2.18**	0.0260	0.399	0.0570	0.79
THU(A)	0.0820	1.38	0.1520	3.25***	0.1320	2.00**	0.0670	0.93
FRI(A)	0.0550	0.99	0.0080	0.17	0.0350	0.563	0.0080	0.12
TUE(N)	0.0550	0.85	-0.0020	-0.03	0.1130	1.58*	0.0540	0.68
WED(N)	0.0280	0.45	0.0060	0.11	0.0250	0.367	0.0310	0.40
THU(N)	-0.0050	-0.08	0.0390	0.79	0.0590	0.845	0.1330	1.76*
FRI(N)	0.0600	0.87	-0.0160	-0.29	0.0010	0.008	-0.1050	-1.25

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

TUE/WED/THU/FRI (A) – days of the week when at least one of the macroeconomic indicators listed in Table 5-8 is announced
TUE/WED/THU/FRI (N) – days of the week when none of the macroeconomic indicators listed in Table 5-8 is announced

The estimation is based on the following model:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum\gamma_{ia}\,\mathbf{T}_{i,t}\,\mathbf{D(a)}_i + \sum\gamma_{in}\,\mathbf{T}_{i,t}\,\mathbf{D(n)}_i + \sum\beta_{ia}\,\mathbf{W}_{i,t}\,\mathbf{D(a)}_i + \sum\beta_{in}\,\mathbf{W}_{i,t}\,\mathbf{D(n)}_I + \sum\delta_{ia}\,\mathbf{Th}_{i,t}\,\mathbf{D(a)}_i + \sum\delta_{in}\,\mathbf{Th}_{i,t}\,\mathbf{D(n)}_i + \sum\eta_{ia}\,\mathbf{F}_{i,t}\,\mathbf{D(a)}_i + \sum\eta_{in}\,\mathbf{F}_{i,t}\,\mathbf{D(n)}_i + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$T_{i,t}$, $W_{i,t}$, $Th_{i,t}$, $F_{i,t}$, $S_{i,t}$, and $S_{i,t}$ are the dummy variables for Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday at time t
D(a) is the dummy variable for the announcements days, while D(n) is the dummy variable for the non-announcements days
ε_{it} is the error term

Table 6-3. Day of the Week Effect (Robustness Test)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	B*i*	t-stats	βi	t-stats
Constant	-0.0010	-0.15	-0.0060	-0.64	-0.0070	-0.48	-0.0140	-0.86
THU	0.0340	1.15	0.0710	2.95***	0.0720	2.11**	0.0790	2.16**

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

The estimation is based on the following model:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_i \, \mathbf{Th}_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$Th_{i,t}$ is the dummy variables for Thursday at time t
ε_{it} is the error term

Table 6-4. January Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0123	0.99	0.0129	1.27	0.0158	1.10	0.0085	0.55
Jan	-0.0900	-2.11**	-0.0662	-1.88*	-0.1048	-2.10**	-0.0825	-1.55

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-statistics	B*i*	t-statistics	βi	t-statistics	βi	t-statistics
Constant	0.0120	0.72	0.0165	1.13	0.0141	0.68	0.0008	0.03
Jan	-0.0970	-1.69*	-0.0881	-1.75*	-0.0943	-1.31	-0.0253	-0.30

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-statistics	B*i*	t-statistics	βi	t-statistics	βi	t-statistics
Constant	0.0126	0.69	0.0094	0.66	0.0175	0.87	0.1588	0.83
Jan	-0.0831	-1.32	-0.0450	-0.91	-0.1150	-1.66*	-0.1381	-2.10*

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

The estimation is based on the following model:

$$R_{i,t} = \alpha_0 + \sum \beta_i J_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$J_{i,t}$ is the dummy variables for January at time t
ε_{it} is the error term

Table 6-5. January Effect (by month)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0800	-1.90*	-0.0500	-1.59	-0.0900	-1.87*	-0.0700	-1.45
FEB	0.0690	1.17	0.0130	0.26	0.0960	1.39	0.1110	1.50
MARCH	0.0910	1.59	0.0760	1.60*	0.1040	1.55	0.0870	1.21
APR	0.0570	0.98	0.0600	1.26	0.0540	0.8	0.0870	1.21
MAY	0.1040	1.80*	0.0370	0.78	0.1290	1.93*	0.0890	1.24
JUNE	0.1190	2.06**	0.1100	2.32**	0.1090	1.62	0.1060	1.47
JULY	0.0810	1.41	0.0450	0.95	0.1170	1.75*	0.0310	0.43
AUG	0.0480	0.83	0.0230	0.49	0.0700	1.04	0.1000	1.41
SEP	0.1530	2.63***	0.1400	2.92**	0.1970	2.90***	0.0870	1.2
OCT	0.0840	1.48	0.0840	1.79*	0.0900	1.35	0.1340	1.87*
NOV	0.0310	0.53	0.0060	0.12	0.0240	0.35	0.0110	0.15
DEC	0.1520	2.64***	0.1320	2.78***	0.1630	2.41*	0.0630	0.87

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-statistics	βi	t-statistics	βi	t-statistics	βi	t-statistics
Constant	-0.0850	-1.55	-0.0700	-1.49	-0.0800	-1.17	-0.0300	-0.3
FEB	0.1220	1.54	0.0960	1.38	0.1200	1.21	0.1310	1.12
MARCH	0.1500	1.95*	0.1110	1.65*	0.1630	1.69*	0.0490	0.43
APR	0.0530	0.69	0.0670	0.98	0.0250	0.26	0.0580	0.51
MAY	0.0940	1.22	0.0650	0.96	0.1130	1.17	0.0050	0.05
JUNE	0.1190	1.53	0.1300	1.92*	0.0860	0.89	0.0790	0.7
JULY	0.0840	1.09	0.0410	0.6	0.1030	1.06	-0.0800	-0.68
AUG	0.0630	0.82	0.0580	0.86	0.0890	-0.35	-0.0700	-0.62
SEP	0.1700	2.17*	0.1310	1.91*	0.1790	1.83*	0.0210	0.18
OCT	0.1580	2.05**	0.1460	2.16*	0.1580	1.64*	0.1510	1.34
NOV	-0.0260	-0.33	0.0310	0.45	-0.0800	-0.81	-0.1100	-0.95
DEC	0.0740	0.96	0.0890	1.31	0.0700	0.72	0.0410	0.36

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-statistics	βi	t-statistics	βi	t-statistics	βi	t-statistics
Constant	-0.0700	-1.17	-0.0400	-0.76	-0.0900	-1.47	-0.1200	-1.94*
FEB	0.0180	0.21	-0.0700	-0.99	0.0730	0.77	0.0930	1.02
MARCH	0.0330	0.38	0.0410	0.62	0.0440	0.49	0.1230	1.39
APR	0.0600	0.69	0.0530	0.79	0.0830	0.89	0.1150	1.29
MAY	0.1120	1.33	0.0090	0.14	0.1450	1.56	0.1690	1.91*
JUNE	0.1200	1.40	0.0910	1.37	0.1320	1.41	0.1310	1.46
JULY	0.0780	0.92	0.0480	0.73	0.1320	1.42	0.1350	1.52
AUG	0.0330	0.39	-0.0100	-0.16	0.0500	0.54	0.2690	3.04**

SEP	0.1360	1.59	0.1480	2.22**	0.2140	2.28*	0.1510	1.69*
OCT	0.0130	0.15	0.0250	0.38	0.0240	0.25	0.1170	1.32
NOV	0.0830	0.96	-0.0200	-0.28	0.1200	1.28	0.1250	1.39
DEC	0.2310	2.69**	0.1760	2.6***	0.2550	2.71***	0.0840	0.93

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

The estimation is based on the following model:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_i \mathbf{M}_{i,t} + \varepsilon_{it}$$

where:
$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$M_{i,t}$ is the dummy variables that takes value of one when day t is in a month from February to December and zero otherwise
ε_{it} is the error term

Table 6-6. April Effect for USD/GBP

1994-2003

	USD/GBP	
	B*i*	t-stats
Constant	0.0333	1.06
Apr(5)	-0.1530	-2.04**
Constant	0.0055	0.54
Apr(5-30)	0.0279	0.72

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

Apr(5) – the first five business days in April
Apr(5-30) –all business days in April, excluding the first five

The estimation is based on the following models:

$$R_{i,t} = \alpha_0 + \sum \alpha_i \, Apr_{(5)i,t} + \varepsilon_t \quad \textbf{(non April days are excluded)}$$
$$R_{i,t} = \alpha_0 + \sum \beta_i \, Apr_{(5\text{-}30)i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$Apr_{(5)i,t}$ is the dummy variables that takes value of one when day t is in the first five days in April and zero otherwise
$Apr_{(5\text{-}30)i,t}$ is the dummy variables that takes value of one when day t is in April after 5th and zero otherwise
ε_{it} is the error term

Table 6-7. First Half of a Month Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0040	0.22	0.0310	2.27**	0.0150	0.78	-0.0010	-0.06
FH	0.0020	0.086	-0.0480	-2.46**	-0.0170	-0.60	0.0060	0.19

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0220	0.99	0.0410	2.12**	0.0220	0.77	0.0010	0.04
FH	-0.0370	-1.15	-0.0650	-2.35**	-0.0310	-0.78	-0.0050	-0.11

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	Bi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	-0.0140	-0.57	0.0210	1.09	0.0090	0.34	-0.0040	-0.14
FH	0.0400	1.14	-0.0310	-1.13	-0.0030	-0.07	0.0160	0.45

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

FH – the first fifteen business days in a month

The estimation is based on the following model:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_{i(fh)}\, \mathbf{FH}_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$FH_{i,t}$ is a dummy variable that is equal to one when day t is in the first half of the month, and zero otherwise,
ε_{it} is the error term

Table 6-8. Turn of the Month Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0050	0.34	0.0020	0.18	0.0060	0.34	0.0100	0.56
BEG	0.0210	0.59	0.0160	0.57	0.0370	0.91	-0.0250	-0.59
END	-0.0210	-0.60	0.0210	0.74	-0.0260	-0.65	-0.0320	-0.75

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	Bi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0180	0.94	0.0110	0.64	0.0130	0.53	0.0120	0.44
BEG	-0.0500	-1.08	-0.0210	-0.52	0.0030	0.05	-0.0500	-0.74
END	-0.0470	-1.02	0.0110	0.28	-0.0470	-0.82	-0.0450	-0.66

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0080	-0.36	-0.0060	-0.37	-0.0010	-0.04	0.0070	0.33
BEG	0.0900	1.76*	0.0540	1.34	0.0700	1.24	-0.0010	-0.01
END	0.0050	0.10	0.0300	0.75	-0.0050	-0.08	-0.0200	-0.38

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

BEG – the first three business days in any month
END – the last three business days in any month

The estimation is based on the following models:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_{i(fh)}\, \mathbf{TOM}_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$S_{i,t}$ is a dummy variable that is equal to one when day t is one of the first 3 days of the month, and zero otherwise
$END_{i,t}$ is a dummy variable that is equal to one when day t is one of the last 3 days of the month, and zero otherwise
ε_{it} is the error term

Table 6-9. Turn of the Month Effect (Robustness Test)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0048	0.34	0.0021	0.18	0.0056	0.34	0.0097	0.56
TOM	-0.0001	-0.01	0.0186	0.86	0.0052	0.17	-0.029	-0.88

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

TOM –either the first or the last three business days in any month

The estimation is based on the following models:

$$R_{i,t} = \alpha_0 + \sum \beta_{i(s)} S_{i,t} + \sum \beta_{i(end)} END_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$TOM_{i,t}$ is a dummy variable that is equal to one when day t is one of the last or first 3 days of the month, and zero otherwise
ε_{it} is the error term

Table 6-10. Turn of the Year Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	Bi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0020	0.15	0.0070	0.69	0.0050	0.33	0.0050	0.31
TOY	0.1280	1.65*	0.0230	0.35	0.1020	1.12	-0.1330	-1.37

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	Bi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0050	0.32	0.0110	0.77	0.0080	0.41	0.0030	0.14
TOY	-0.0550	-0.52	-0.0750	-0.82	-0.0870	-0.66	-0.1930	-1.26

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	Bi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0020	-0.08	0.0030	0.20	0.0010	0.06	0.0060	0.32
TOY	0.3150	2.68***	0.1250	1.35*	0.3010	2.33**	-0.0760	-0.61

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

TOY –either the first or the last three business days in any year

The estimation is based on the following models:

$$R_{i,t} = \alpha_0 + \sum \beta_i TOY_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$TOY_{i,t}$ is a dummy variable that is equal to one when day t is in the first or last three business days of the year, and zero otherwise
ε_{it} is the error term

Table 6-11. Turn of the Year Effect (Robustness Test)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0030	0.24	0.0060	0.59	0.0070	0.50	0.0060	0.36
TOY	0.0210	0.48	0.0200	0.56	-0.0080	-0.14	-0.0530	-0.92

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

TOY –either the first or the last ten business days in any year

The estimation is based on the following models:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_i TOY_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$TOY_{i,t}$ is a dummy variable that is equal to one when day t is in the first or last ten business days of the year, and zero otherwise
ε_{it} is the error term

Table 6-12. Turn of the Year Effect (Robustness Test)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0020	0.24	0.0070	0.69	0.0053	0.38	0.0050	0.35
DEC	0.1740	1.58**	0.0990	1.09	0.1800	1.47**	0.0100	0.07
JAN	0.0570	0. 52	-0.0530	-0.58	-0.0400	-0.32	-0.3260	-2.39**

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

DEC –the last three business days in December
JAN –the first three business days in January

The estimation is based on the following models:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_i \mathbf{DEC}_{i,t} + \sum \beta_i \mathbf{JAN}_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$DEC_{i,t}$ is a dummy variable that is equal to one when day t is in the last three business days in December, and zero otherwise
$JAN_{i,t}$ is a dummy variable that is equal to one when day t is in the first three business days in January, and zero otherwise
ε_{it} is the error term

Table 6-13. Holiday Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0060	0.51	0.0110	1.07	0.0140	0.93	0.0140	0.90
PREH	0.0940	1.53	0.0460	0.91	0.0340	0.48	-0.0660	-0.86
POSTH	-0.0530	-1.74*	-0.0430	-1.71*	-0.0660	-1.86*	-0.1200	-3.15**

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0100	0.59	0.0150	1.01	0.0180	0.88	0.0170	0.71
PREH	0.0510	0.63	0.0380	0.53	-0.0340	-0.33	-0.0660	-0.55
POSTH	-0.0890	-2.18**	-0.0800	-2.25**	-0.1100	-2.16**	-0.1870	-3.14***

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0030	0.16	0.0070	0.50	0.0090	0.42	0.0110	0.55
PREH	0.1360	1.49	0.0550	0.76	0.1020	1.02	-0.0660	-0.69
POSTH	-0.0180	-0.39	-0.0070	-0.18	-0.0230	-0.45	-0.0530	-1.11

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

PREH –the days preceding US official holidays
POSTH – the days following US official holidays

The estimation is based on the following models:

$$\mathbf{R_{i,t} = \alpha_0 + \sum \beta_i PREH_{i,t} + \sum \beta_i POSTH_{i,t} + \varepsilon_{it}}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate *i* on day *t*, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate *i* on day *t*, while P_{t-1} denotes the close exchange rate *i* on day *t-1*;
$PREH_{i,t}$ is a dummy variable that is equal to one when day t precedes a US official holiday, and zero otherwise
$POSTH_{i,t}$ is a dummy variable that is equal to one when day t follows a US official holiday, and zero otherwise
ε_{it} is the error term

Table 6-14. Holiday Effect (Non US Holidays)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β*i*	t-stats	**B*i***	t-stats	**β*i***	t-stats	**β*i***	t-stats
Constant	0.0010	0.07	0.0050	0.51	0.0070	0.52	0.0020	0.11
PREH	0.0670	0.92	0.1220	1.89*	0.0200	0.18	0.0190	0.27
POSTH	0.0570	1.56	0.0270	0.82	0.0560	1.04	-0.0090	-0.26

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

PREH –the days preceding official holidays in Germany, UK, Switzerland and Japan
POSTH – the days following official holidays in Germany, UK, Switzerland and Japan

The estimation is based on the following models:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_i \mathbf{PREH}_{i,t} + \sum \beta_i \mathbf{POSTH}_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate *i* on day *t*, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate *i* on day *t*, while P_{t-1} denotes the close exchange rate *i* on day *t-1*;
$PREH_{i,t}$ is a dummy variable that is equal to one when day t precedes a non-US official holiday, and zero otherwise
$POSTH_{i,t}$ is a dummy variable that is equal to one when day t follows a non-US official holiday, and zero otherwise
ε_{it} is the error term

Table 6-15. Holiday Effect (Non US Holidays[22])

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	Bi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0050	0.37	0.0070	0.69	0.0090	0.66	-0.0010	-0.07
PREH	-0.0060	-0.06	0.0580	0.73	-0.1280	-0.87	0.0410	0.55
POSTH	0.0370	0.87	0.0470	1.18	0.0800	1.09	0.0130	0.35

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

PREH –the days preceding non-US official holidays, which does not coincide with the US holiday
POSTH – the days following non-US official holidays, which does not coincide with the US holiday

The estimation is based on the following models:

$$\mathbf{R}_{i,t} = \alpha_0 + \sum \beta_i \mathbf{PREH}_{i,t} + \sum \beta_i \mathbf{POSTH}_{i,t} + \varepsilon_{it}$$

where:

$R_{i,t}$ is logarithmic change in the FX rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate i on day t, while P_{t-1} denotes the close exchange rate i on day $t-1$;
$PREH_{i,t}$ is a dummy variable that is equal to one when day t precedes a non-US official holiday, which does not coincide with the US holiday, and zero otherwise
$POSTH_{i,t}$ is a dummy variable that is equal to one when day t follows a non-US official holiday, which does not coincide with the US holiday, and zero otherwise
ε_{it} is the error term

[22] non US holidays, which do not coincide with the US holidays

Table 6-16. Holiday Effect (Non December Holidays)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	B*i*	t-stats	βi	t-stats	βi	t-stats
Constant	0.0100	0.78	0.0130	1.30	0.0150	1.01	0.0100	0.63
PREH	0.0550	0.80	-0.0050	-0.08	-0.0030	-0.03	-0.0290	-0.34
POSTH	-0.0880	-2.58***	-0.0600	-2.11**	-0.0760	-1.91*	-0.1120	-2.62***

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

PREH –the days preceding US official holidays (apart from December holidays)
POSTH – the days following US official holidays (apart from December holidays)

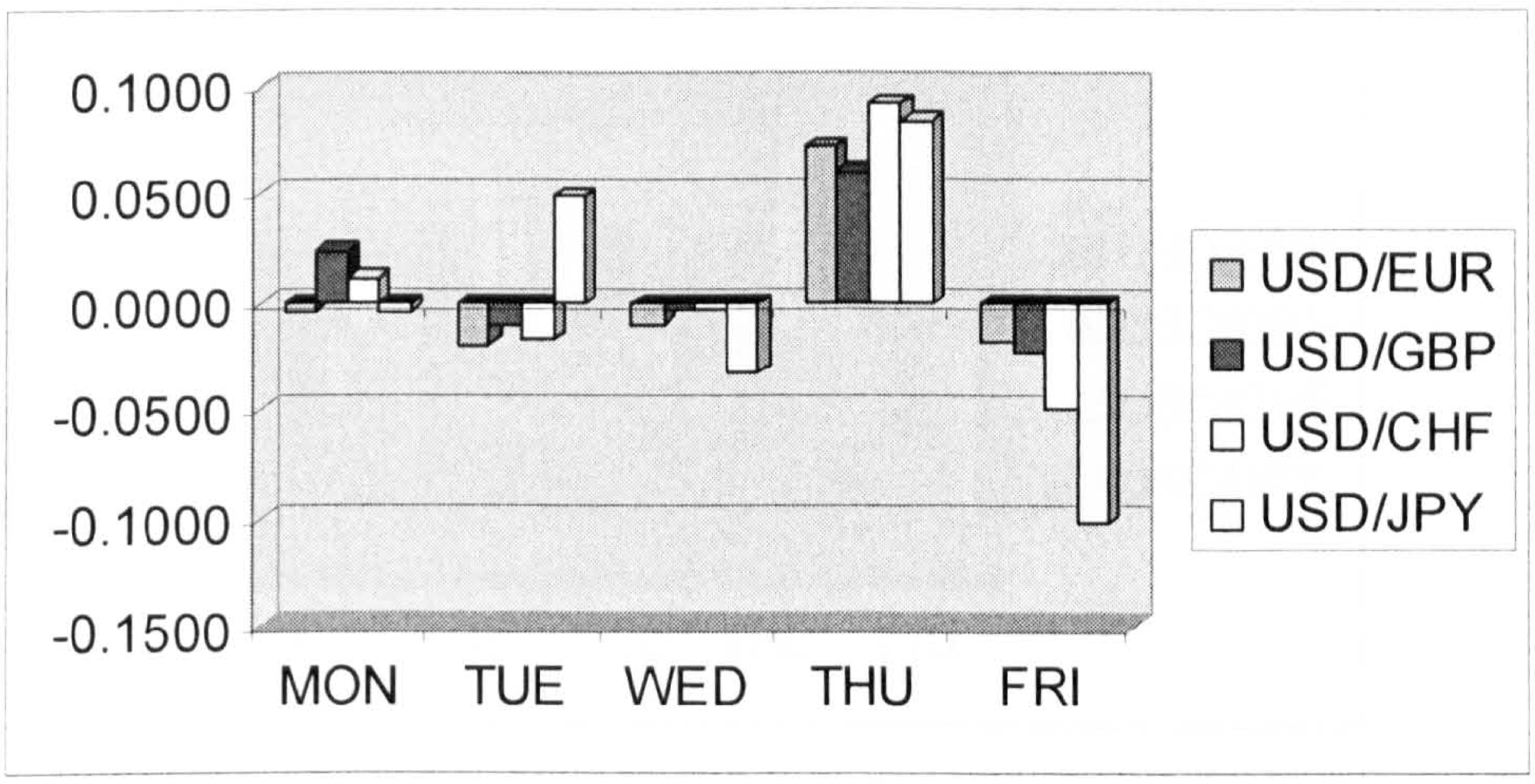
The estimation is based on the following models:

$$R_{i,t} = \alpha_0 + \sum \beta_i PREH_{i,t} + \sum \beta_i POSTH_{i,t} + \varepsilon_{it}$$

where:

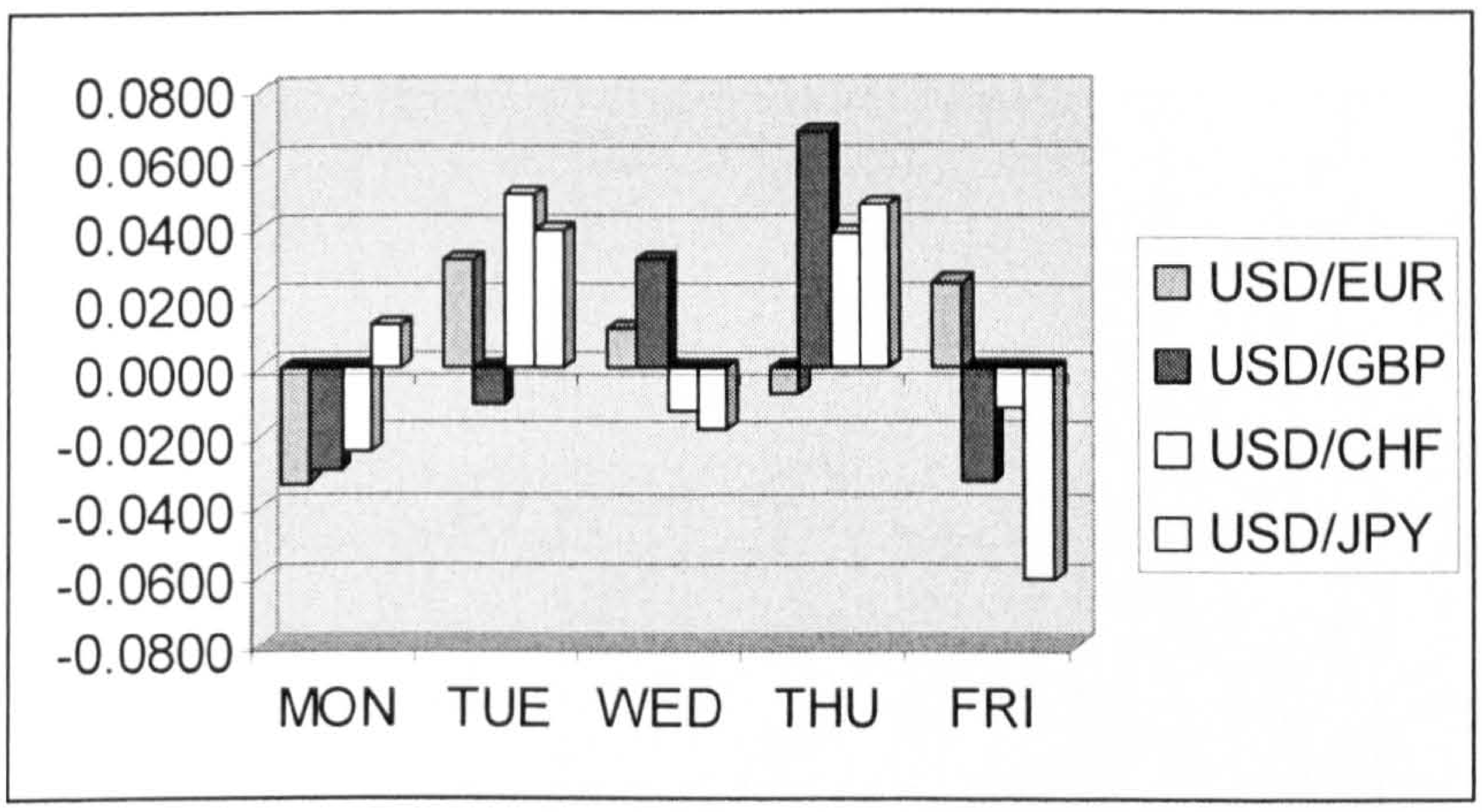
$R_{i,t}$ is logarithmic change in the FX rate *i* on day *t*, equal to ln (Pt/Pt-1), where P_t denotes the close exchange rate *i* on day *t*, while P_{t-1} denotes the close exchange rate *i* on day *t-1*;
$PREH_{i,t}$ is a dummy variable that is equal to one when day t precedes a US official holiday (apart from December holidays), and zero otherwise
$POSTH_{i,t}$ is a dummy variable that is equal to one when day t follows a US official holiday (apart from December holidays), and zero otherwise
ε_{it} is the error term

Figure 6-1. Average Daily Rates of Return by the Day of the Week (1994-1999)



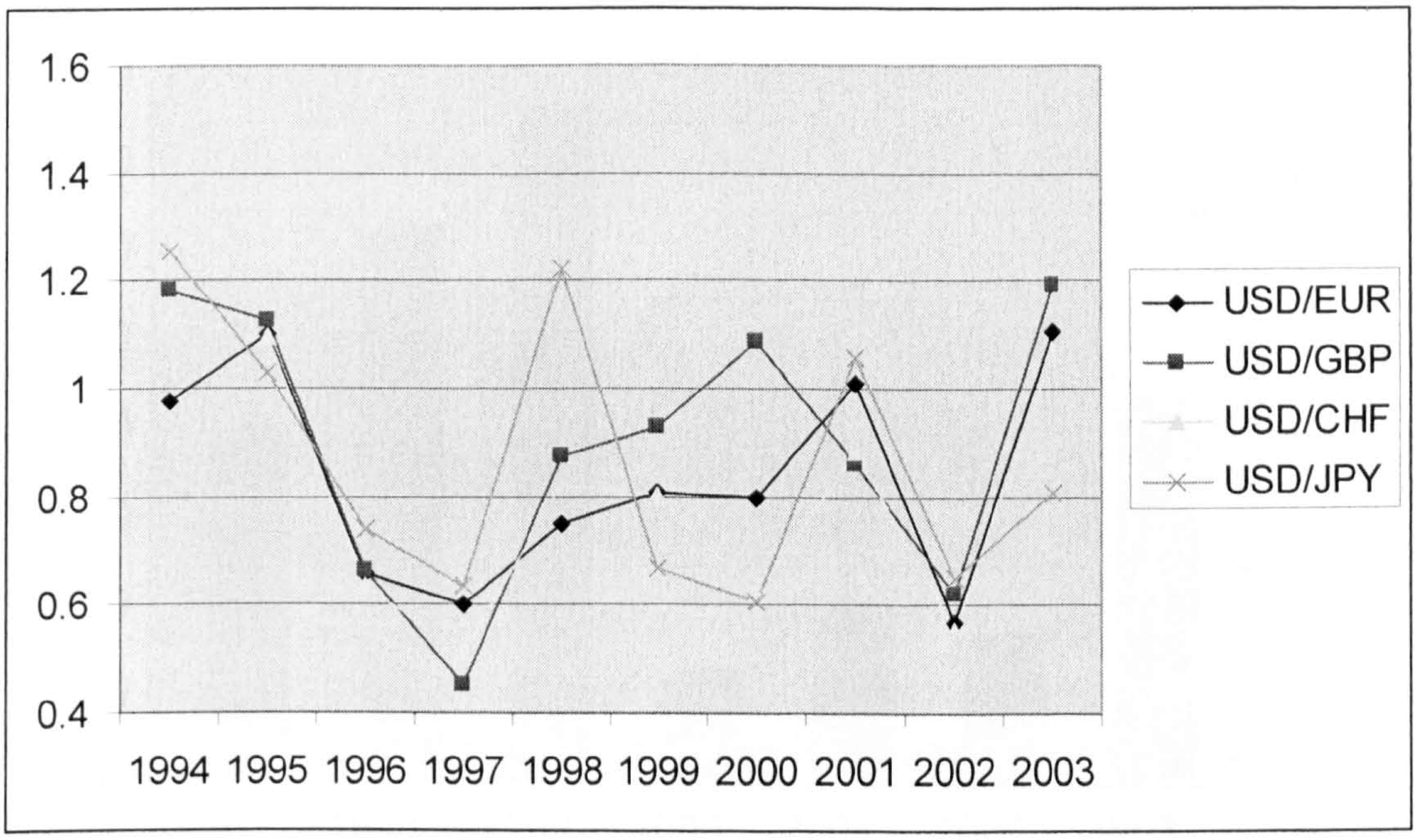
The figure graphically reports the average daily foreign exchange returns by days of the week. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for a five-year sub-period from January 1994 through December 1998. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Figure 6-2. Average Daily Rates of Return by the Day of the Week (1999-2004)



The figure graphically reports the average daily foreign exchange returns by days of the week. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for a five-year sub-period from January 1999 through December 2003. The returns are calculated as ln (p_t/p_{t-1}), where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

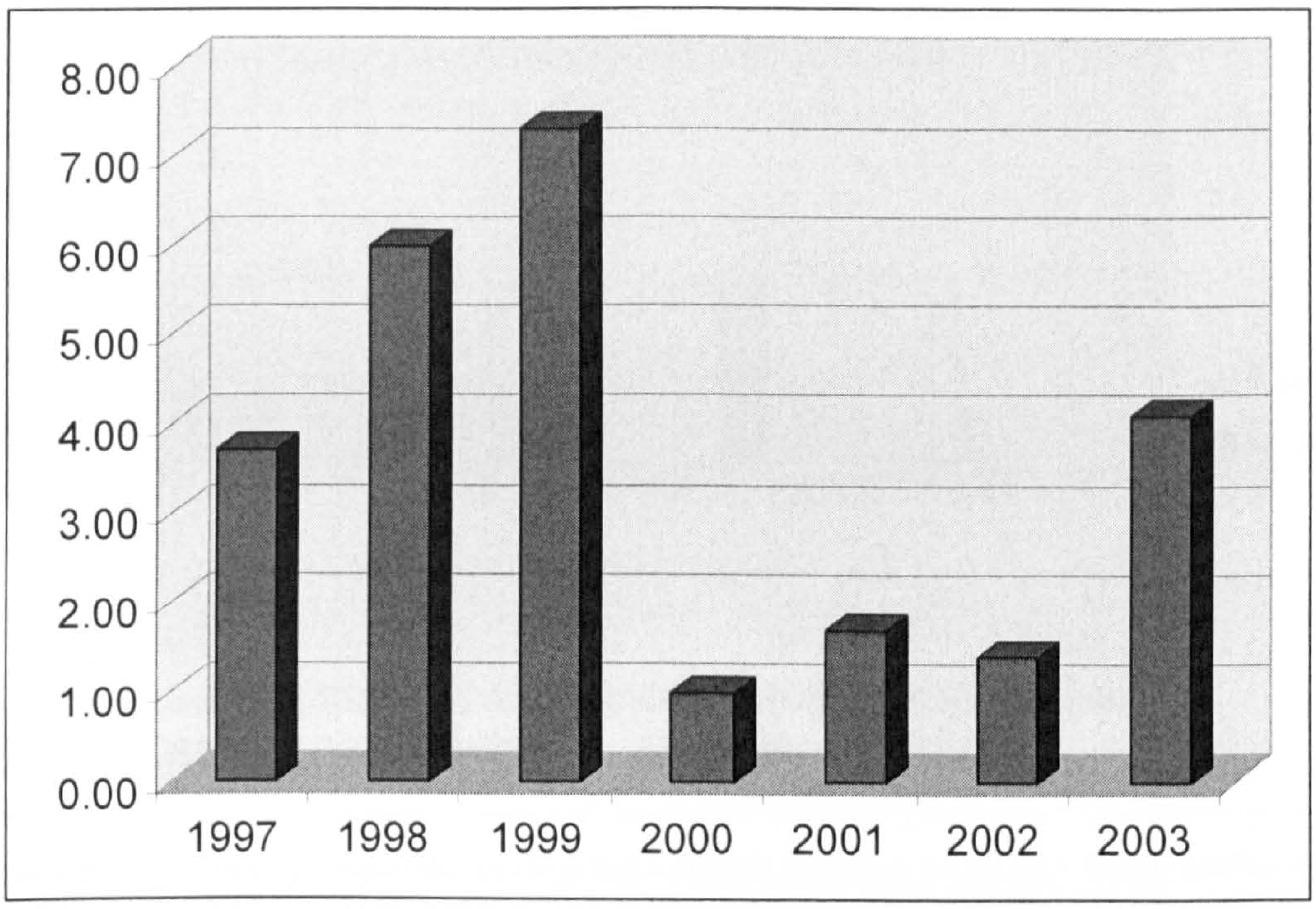
Figure 6-3. Power Ratios for Major Exchange Rates



The figure graphically reports the power ratio for the average daily foreign exchange rates in each year in the period of 1994 - 2003. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP). The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1. The power ratio is calculated as below:

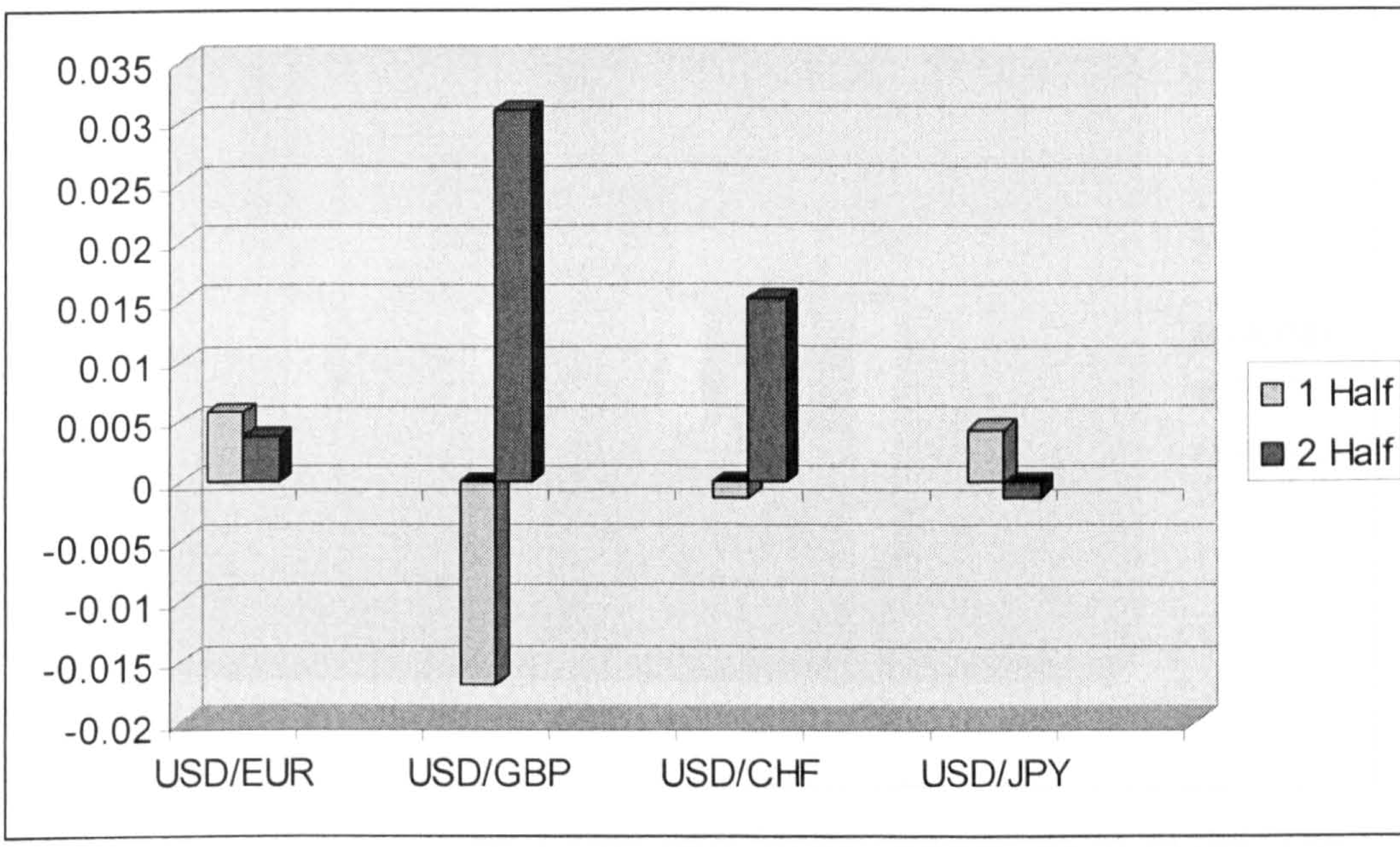
$R_j = (1+\text{January Return})^{12}$, where power 12 is used because there are 12 months in the year.
$R_y = (1+\text{Return on the year})$
R_j/R_y -power ratio since R_j is a factor of power

Figure 6-4. GDP Growth Rates for Each Year in 1997-2003



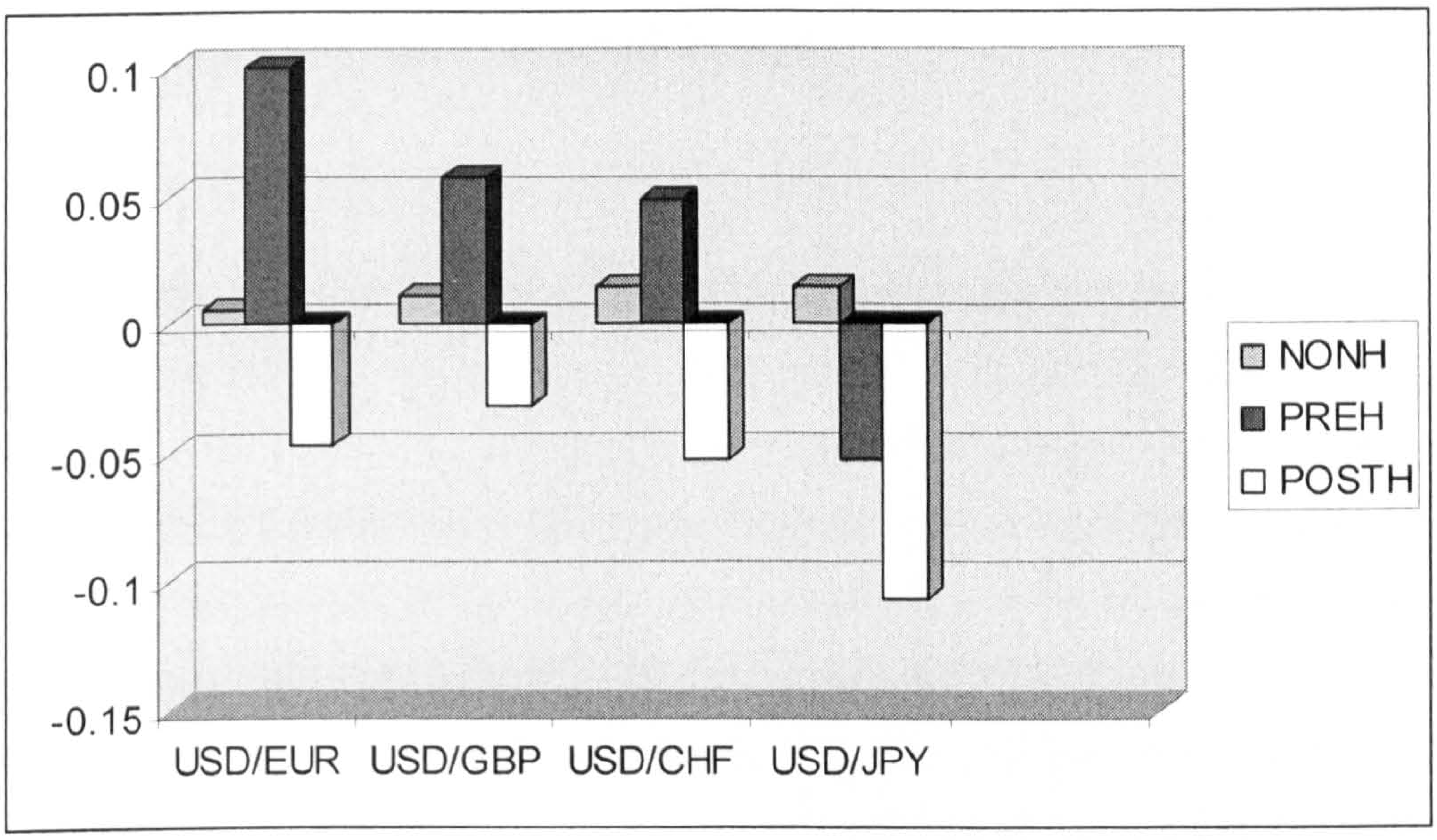
The figure graphically reports the final US GDP growth rate in each year in the period of 1997 - 2003

Figure 6-5. First Half of a Month vs. Second Half of a Month Return



The figure graphically reports the average daily foreign exchange returns in the first half vs. second half of a month. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for a ten-year sample period from January 1994 through December 2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

Figure 6-6. Holiday Effect



The figure graphically reports the average daily foreign exchange returns on days prior to official US holiday, on days following the holiday and on non holiday days. The exchange rates are the rates of US Dollar (USD) to Euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and British pound (GBP) for a ten-year sample period from January 1994 through December 2003. The returns are calculated as $\ln(p_t/p_{t-1})$, where p_t is the close exchange rate on day t, and p_{t-1} is the close exchange rate on the day t-1.

CHAPTER 7. SEASONALITY PATTERNS IN THE FX IMPLIED VOLATILITIES (EMPIRICIAL)

After examining the seasonality patterns and anomalies in the FX return series, we focus on the FX implied volatility patterns in this chapter. We find a strong evidence of the day of the week effect[1] in the FX implied volatilities, which has already been documented for the equity and currency futures implied volatilities by Harvey and Huang (1991) and Ederington and Lee (1996), respectively. Our most significant contribution to the existing literature is that the day of the week effect has become more obvious following the introduction of the euro. We try to explain this phenomena by the euro being more volatile currency than the DM (Heaney and Swieringa, 2003), the concentration of euro related announcements on Thursday and Friday, the strengthened impact of the private information based trading on the implied volatility (McGroarty et. al, 2005) and finally by the USD depreciation and the theory that seasonality patterns become more obvious in a declining rather than rising markets (Arsad and Coutts, 1997 and Steeley, 2001).

We also find an evidence of the strong turn of the year[2] effect in the FX implied volatilities. Although a fall in the equity implied volatility starts two days prior to the year end (Rogalski and Maloney, 1989), we found FX implied volatility starting to decline only after two days following the turn of the year. This finding is a major contribution of this study and could be explained by the fact that the seasonality patterns in the currency implied volatilities, including the turn of the year effect, are relatively longer lived, compared to those in other markets' volatilities. We note that the turn of the year effect is more significant in the sample period preceding the introduction of euro and explain a declining trend in the turn of the year effect over time by the diminishing January effect in the financial markets.

[1] indicated by the positive implied volatility changes on Monday and Tuesday and negative implied volatility changes on Thursday and Friday

[2] The results suggest that the implied volatility tends to increase during the last 30 and the first 2 days of the year, before declining between trading +2 and +10.

We do not find a strong evidence of the monthly or quarterly patterns in the FX implied volatilities, noting that the quarterly patterns became more significant in the second sample period of 1999-2003, which could be due to USD depreciation and the fact that seasonality patterns are more obvious in the declining markets. We find some, though not very significant evidence of the turn of the month effect in the FX implied volatilities and report decreased implied volatility prior to and increased implied volatility following the holiday.

We examine a day of the week effect in the implied volatility series in section 7.1. Section 7.2 focuses on the intra-monthly patterns, while section 7.3 examines a turn of the year effect in the FX implied volatilities. We study holiday effect in section 7.4 and investigate quarterly patterns in section 7.5. Finally, section 7.6 provides a brief summary of the chapter.

7.1. Day of the Week Effect in the FX Implied Volatilities

As Table 7-1 shows and consistent with the hypothesis 9, the sign of the regression coefficients for all FX rates is positive for Monday and Tuesday and negative for Thursday and Friday. The most significant results are obtained for Monday, which is consistent with the existing literature on the US bond (Morse, 1990), commodities (Chang et. al, 1997), equity (Van der Sar, 2003, Kiymaz and Berument, 2003, Tanizaki, 2004 and Yalcin and Yusel, 2006) and finally currency (Taylor, 1987 and Harvey and Whaley, 1992) markets.

Harvey and Whaley (1992) tried to explain high Monday volatility by the traders' trading patterns, arguing that as traders reopen their positions on Monday, a buying pressure causes the implied volatility to rise. Foster and Viswanathan (1990) argued that since traders use private information accumulated during the weekend before the information is publicly disseminated, volatility is significant on Monday. Although the FX is a 24 hour market, traders prefer trading when the liquidity is high (eg Monday). Tanizaki (2004) also explained significant volatility on Monday at the Japanese equity market by the positive correlation between the amount of information and volatility, and the fact that Monday are followed by a non-trading period of two days, during which a large amount of (both private and public) information is accumulated.

Table 7-1 suggests that the implied volatility tends to be the highest on Monday, slightly declines on Tuesday, and then display a sharp fall on Wednesday, before reaching its lowest levels on Thursday and Friday[3]. Such behavior of the FX implied volatility is in line with Foster and Viswanathan's (1990) private information hypothesis, which predicts monotonically decreasing volatility during the week, assuming that as the week progresses, more and more information is publicly disseminated, resulting in the gradually decreasing volatility. Implied volatility is high when uncertainty is high at the beginning of a trading week following two days of a limited trading. The volatility tends to decline as the source of uncertainty (eg

[3] The coefficients reported for Thursday and Friday are negative for all the exchange rates, and significant at 5% significance level for USD/EUR and USD/GBP.

news announcements) disappears as the week progresses. Harvey and Whaley (1992) also reported an increased implied volatility on Monday and decreased volatility on Friday for the implied volatility of S&P index. Consistent with the private information hypothesis, Harvey and Whaley (1992) explained significant fall in the implied volatility on Friday by the traders' trading patterns and the increased selling pressure due to many traders closing their positions before the weekend.

As expected, implied volatility on Saturday and Sunday is not significant, apart from only USD/CHF on Saturday and USD/JPY on Sunday. The sign of Saturday coefficient is negative for all exchange rates, apart from USD/JPY, and that of Sunday coefficient is positive for all exchange rates, apart from USD/EUR. This is consistent with Muller et. al (1990), who concluded that volatility is low on weekends compared to the trading days, and tend to be higher on Sunday than on Saturday. Relatively high Sunday volatility is due to a trading activity in some Middle Eastern markets, which are open on Sunday and early Monday morning activity in East Asian markets, which coincide with Sunday nights in GMT. Insignificant Saturday coefficients could also be due to a limited number of observations[4]. Statistically significant Sunday volatility for USD/JPY is due to the fact that early Monday morning activity in East Asian markets coincide with Sunday nights in GMT. Since traders start using private information accumulated during the weekend during the last hour of Sunday (GMT), the impact of the private information based trading in USD/JPY is spread over GMT Sunday and Monday. This explanation is also consistent with another observation that Monday positive volatility change is significant at 1% significance level for USD/EUR, USD/GBP and USD/CHF, but only at 10% significance level for USD/JPY.

We compare our findings with the existing ones in section 7.1.1. In section 7.1.2, we try to explain the day of the week effect in the FX implied volatilities by the macro news announcements. Finally, in section 7.1.3, we compare day of the week effect in pre and post euro periods.

[4] there are only 124 observations out of a total of 2714 (4.5%) for USD/CHF on Saturday

7.1.1. Our Results Versus Existing Findings

The first contribution of this chapter to the existing literature is that we show that the intraweek patterns in the implied volatilities (falling volatility as a week progresses) documented by Harvey and Whaley (1992) for the equity index and by Ederington and Lee (1996) for the currency futures exist in the FX cash market. However, the results contradict the findings of some empirical studies on the intraweek volatility patterns in the equity (Berument and Kiymaz, 2001 and Chukwuogor – Ndu, 2006) and currency (Han et. al, 1999, Ederington and Lee, 2001 and Kim and Kim, 2004). Whilst we define volatility as the implied volatility, in other studies volatility is proxied by the historical volatility measures, such standard deviation and variance, or by the conditional volatility measures, such as ARCH or GARCH volatilities[5].

It is more difficult to explain a different results reported by us and Kim and Kim (2004), who concluded that the FX implied volatilities tend to be low in the beginning of the week and high in the later part of the week starting from Wednesday. The most obvious explanation is that while Kim and Kim (2004) used volatilities implied from the options on futures contracts for the period from January 1987 to December 1998, we use volatilities implied from the cash options[6] on the FX rates for a more recent period from January 1994 to December 2003. The tendency for the implied volatilities to decline on days with the announcements, which was documented by us and by Kim and Kim (2004) could become more significant following the introduction of euro. If the currency markets became more volatile after the introduction of euro, as predicted by Masson and Turtelboom (1997) and Eichengreen (2000), the impact of the announcements on the currency implied

[5] The main difference is that the historical and conditional volatilities are the backward-looking measure of recent volatility, while volatilities implied from the options prices, are an ex ante measure of volatility and measure volatility or uncertainty expected over the useful life of the option.
[6] The use of the cash implied volatilities helps to avoid the problem of thin trading and non-trading effect (Figlewski, 1997), which arises when volatilities implied from the options on the futures markets are used and is caused by the lack of trading during particular times of a day, resulting in the full impact of large information event being spread over two or more days. Besides, over-the-counter (OTC) markets, from which cash implied volatilities are drawn, are more liquid than the market for the currency futures.

volatilities is also likely to become more significant, which would explain decreased volatility on Thursday and Friday.

Besides, the ability to use implied volatility as an accurate proxy for the market volatility depends on both the accuracy of the option-pricing model and on the reliability of the information used in the estimation process. Kim and Kim (2004) used Knight Ridder implied volatilities, which are calculated based on the Black's (1976) option pricing model. The European option-pricing model of Black (1976) used by Kim and Kim (2004) does not take into account the value of early exercise, which might result in enhanced pricing biases in the implied volatilities, due to the time to maturity and degree of moneyness variables[7]. Another potential problem with the model used by Kim and Kim (2004) is that relatively short-term options with ten days to maturity have been used to extract implied volatilities. Shorter-term options are mainly used as hedging tools by market makers, resulting in the volatilities of such options being very variable and higher than those of longer-term options[8]. In addition, Kim and Kim (2004) define Monday volatility as the volatility change from Friday close to Monday close, while we define Monday volatility as the change in the implied volatility from 00:00 GMT to 24:00 GMT on Monday. Therefore, the Monday volatility as proxied by Kim and Kim (2004) includes a weekend, characterized by relatively low activity, which explains low Monday volatility.

7.1.2. Day of the Week Effect in the FX Implied Volatilities & News Announcements

In spite of the attempts to explain the intraweek implied volatility patterns by the private information hypothesis, most studies linked the behaviour of the implied volatility in the last days of the business week to the scheduled macroeconomic announcements. Since, many US announcements tend to be released on Thursday and Friday, it is not surprising that the uncertainty, as measured by the implied

[7] Harvey and Whaley (1991) stress the danger of estimating implied volatilities from a European option-pricing model when the true nature of the options are American.
[8] Feinstein (1989) and Heynen et. al (1994) argued that the ability of the implied volatility to represent the market's estimate of the underlying asset's volatility over option's life is most accurate for the options with the expiry date of at least 3 weeks.

volatility, tends to decline on these days. Besides, many UK[9] and Eurozone[10] related announcements tend to occur on Thursday. This explanation is in agreement with Andersen and Bollerslev (1998), who concluded that the clustering of the public information releases on Thursday and Friday explains the day of the week effect and Ederington and Lee (1996), who also explained low FX implied volatility on Friday by the release of the scheduled announcements, and mainly the employment report in USA. Ederington and Lee (1996) attributed high Monday implied volatility to a relatively small number of the scheduled macroeconomic announcements on Monday, as documented by Harvey and Whaley (1992). This explanation is also consistent with Ederington and Lee (2001), who confirmed that volatility increases in the beginning of the week, as market anticipates the release of the scheduled announcements in the second part of the week.

Ederington and Lee (1996) hypothesized that if the announcement effect explains the intraweek patterns in the implied volatility, the implied volatility should fall on Friday with scheduled announcements, but rise on Friday without announcements. Given that the private information hypothesis also predicts increased implied volatility on Monday and decreased volatility on Friday, a fall in the implied volatility on Friday would be consistent with both the announcement effect and the private information hypothesis. This makes it more difficult to explain the implied volatility patterns, because most tests would be joint tests of both the announcement effect and the private information hypothesis. Instead, we hypothesize that implied volatilities should fall on both announcement and non-announcement days, which is consistent with both theories. However, if the scheduled announcements explain a day of the week effect in the implied volatilities, a fall in the implied volatilities on Thursday and Friday should be more significant on days with the announcements and less significant on days without the announcements. As suggested by Ederington and Lee (1996), a release of the important macroeconomic news reduces uncertainty and therefore causes a fall in the implied volatility. In the absence of the important news announcements, the fall in the implied volatility (if any) should not be significant.

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[9] UK announcements are clustered on Tuesday, Wednesday and Thursday, and scarcely occur on Monday and Friday ((Steeley (2001))

[10] announcement of the interest rates by ECB

The estimates reported in Table 7-2 suggests that Thursday and especially Friday coefficients become more significant when days without the scheduled announcements are excluded[11]. The results confirm the hypothesis 10 that the announcement effect explain the behavior of the implied volatility on Thursday and Friday, and is consistent with Ederington and Lee (1996)[12]. Most Monday and Tuesday coefficients remain positive when announcement days only are considered, however, the results are significant for USD/CHF only. This could be explained by the fact that the upward pressure on the implied volatility following weekends is offset by the downward pressure on the implied volatility resulting from the release of the news announcements. In contrast, Monday coefficients become more significant when announcement days are excluded. This observation is consistent with the view that although announcements tend to impact volatility on Monday, it is private information hypothesis that explains the behavior of the implied volatilities on Monday. Another interesting observation is that all coefficients reported for USD/JPY are negative for the announcement days and positive for non-announcement days. This difference between USD/JPY and the rest of the major exchange rates, could be explained by the fact that early morning activity in East Asian markets coincides with late nights in GMT, and therefore, the impact of the private information based trading in USD/JPY and the impact of the US news announcements is spread over two GMT based days. The findings suggest that both the announcements effect and the private information hypothesis explain day of the week effect in the implied volatility. However, it appears that the private information hypothesis is a more accurate explanation for the increased implied volatility on Monday, and the announcement effect tends to better explain reduced implied volatility on Friday.

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[11] Friday coefficient is significant at 1% significance level for USD/EUR and USD/GBP and at 10% significance level for USH/JPY, while Thursday coefficients are significant at 10% significance level for all currency pairs, apart from USD/JPY, when announcement days only are considered. However, none of the Thursday and Friday coefficients for the days without scheduled announcements are significant at 10% significance level.

[12] Ederington and Lee (1996) reported similar results and suggested that although decreased implied volatility on Friday is mainly due to the announcement effect, the traders' trading patterns has some, though insignificant effect on the implied volatility.

7.1.3. Pre and Post Euro Periods

Our contribution to the existing literature is that the day of the week effect indicated by the increased implied volatility on Monday and decreased implied volatility on Thursday and Friday is much stronger in the post euro period. Whilst the Monday coefficients are statistically significant for all the FX rates in post euro period, in the sample of 1994-1998 the Monday coefficients are positive for the exchange rates of US Dollar to the European currencies, but significant only for USD/CHF. This observation could be explained by the fact that the US dollar and Euro had become more volatile after the introduction of euro (Heaney and Swieringa, 2003), resulting in a more pronounced seasonality patterns.

A hypothesis that Monday effect has become more significant after the introduction of euro could be explained by the strengthened impact of the private information based trading on the implied volatility. McGroarty et. al (2005) studied a link between a private information hypothesis and intraday FX volatility, reporting the results, which suggest that the relation between volatility and volume that confirms Foster and Viswanathan's (1990) model has become more significant in post euro period for USD/EUR and USD/CHF. These findings explain why we observe significant Monday effect in post euro period, but not in the period preceding euro.

In the sample period preceding euro, the Tuesday coefficients are still positive and significant for USD/GBP and USD/CHF, but none of Thursday and Friday coefficients is significant. In the sample period following the euro, all Thursday and Friday coefficients are negative and significant for most FX rates. The results suggest that the decrease in the implied volatility on Thursday and Friday is the phenomenon that occurs only in 1999-2003 period, and implies that the impact of the scheduled announcements on the FX implied volatility increased significantly after the introduction of euro. This could also be explained by the increased USD and Euro volatility in the currency markets after the introduction of euro in 1999 (Heaney and Swieringa, 2003), resulting in more pronounced seasonality patterns. Another potential explanation could be an increased role of euro relative to that of DM and the important news announcements related to Eurozone that tend to be released later in the week. As foreign central banks chose to diversify their asset portfolios away from the dollar, Euro zone related events have become more important. If the foreign central banks hold the significant portion of their asset portfolios in euros, then the events, such as the announcement of the interest rates by the European Central Bank that tend to occur on Thursday, would have a significant impact on the FX volatility. This could explain why we observe a fall in the currency implied volatilities in post - euro sample period, which is not so obvious in the sample period preceding euro.

A strengthening day of the week effect in the implied volatilities could also be explained by the USD depreciation. There is an empirical evidence of the seasonality patterns in the stock market return series changing over time depending on the direction of the market (Fishe et. al, 1993 and Arsad and Coutts, 1997)[13]. If the market direction explains the day of the week effect in the asset return series, it is also likely to impact the intraweek patterns in the implied volatilities, which should become more sensitive to the day of the week effect in a declining rather than a rising market. If this hypothesis is accurate, then the sample period of 1994-1998 would be associated with a relatively weak or no intraweek patterns due to a strong USD in the 1990s. As USD weakened in the post euro period, the day of the week effect has become more significant.

[13] Fishe et. al (1993) and Arsad and Coutts (1997) indicated that the weekend effect in the equity market is much less visible during periods of stock market rises. Steeley (2001) suggested that the weekend effect had disappeared in the UK stock market in the 1990s, reporting significant seasonality patterns for the negative returns and no anomalies for the positive ones.

7.2. Intra- Monthly Effect in the FX Implied Volatilities

We hypothesize that the seasonality in the equity market is reflected in the FX implied volatilities because the same factors impact both markets (discussed in the previous chapters). For example, the tendency of many FX transactions to occur during particular periods (eg financial statement disclosures, payment of the municipal and corporate debt) could explain some intra-monthly and quarterly patterns.

Table 7-3 shows that the implied volatility changes around the turn of any month are larger than those during the remainder of a month, supporting the hypothesis 14 and providing a contribution to the existing literature. The results are more significant in 1994-1998 period for USD/CHF and USD/JPY, and in 1999-2003 period for USD/EUR and USD/GBP. These results are consistent with Martikainen et. al (1995), who found equity implied volatility around the turn of a month to be significantly positive. However, the regression estimates reported by Martikainen et. al (1995) for 5 days preceding and following the turn of a month are significant at 1% significance level, while we report statistically significant results for USD/CHF only[14]. Increased implied volatility around the turn of a month could be explained by the hypothesis proposed by Ogden (1990), who argued that the US economy has substantial payments to private investors, such as salaries and debt interest on the last trading day of the month, which affect equity volatility. The fact that most corporate and municipal debt in the USA is payable on the first and last days of the month, affecting USD volatility, could explain the reported turn of the month effect.

In spite of the strong evidence in support of the turn of the month effect, the results reported in Table 7-3 suggest that there is no evidence of the first half of the

[14] As suggested by Ziemba (1994), the turn of the month effect could be caused by the turn of the year effect. To eliminate the effects of the turn of the year regularity, the analysis is replicated after excluding turn of the years from the sample. The regression estimates also reported in Table 7-3, suggest that the results reported here are not significantly sensitive to the exclusion of the turn of the years. Although, the regression estimates become less significant after excluding turns of the year, all regression coefficients are positive and the one reported for USD/CHF is still statistically significant.

month effect in the FX implied volatilities (hypothesis 13)[15]. The results reported for five-year sample periods are similar to those reported for the entire period of 1994-2003, though estimates are more statistically significant in the post euro sample, providing some support for the hypothesis 2. The results contradict Ariel (1987) and Martikainen et. al (1995)[16], but are consistent with Barone-Adesi and Cyr (1994).

[15] Although the implied volatility changes tend to be lower in the first half of a month, none of the regression coefficients is statistically significant at 10% significance level.
16 Martikainen et. al (1995) studied monthly seasonality patterns in the Finish equity market, using the first 9 days of a month (instead of 15 days), as the proxy for the first half of the month.

7.3. Turn of the Year Effect in the FX Implied Volatilities

Table 7-4 suggests that turn of the year effect exists in the FX implied volatilities, providing support for the hypothesis 15. The FX implied volatility increases during the last and first two days of the year for all exchange rates. The results are also statistically significant for USD/CHF and USD/JPY during the last 10 days of the year and for USD/GBP during the first 10 days of the year. These results are consistent with Rogalski and Tinic (1986) and Rogalski and Maloney (1989), who provided evidence of the statistically significant equity implied volatility around the turn of the year. Turn of the year effect could be explained by the tax loss selling, which affects equity markets and the capital flows across regions. The expected volatility at the FX market, which is the proxy for the market uncertainty, tends to increase as the year end approaches driving implied volatility up. Once the source of uncertainty (year end) disappears, implies volatility falls.

It appears that for all exchange rates, implied volatility starts to increase about a month prior to the turn of the year. Although, none of the $\beta_{i(-30)}$ coefficients is statistically significant, a positive sign of the coefficients indicate that the financial markets expect turn of the year effect in advance. Since implied volatility measures the market's estimate of the underlying asset's volatility over option's life and given that options with the maturity period of 30 days have been used in this study, it is not surprising that the option prices and therefore volatilities implied from these options reflect these patterns 30 days prior to the year-end. The increase in the implied volatility becomes statistically significant between trading day -10 and trading day -2 for USD/CHF and USD/JPY and during the last 2 days of the year for USD/EUR and USD/GBP. Implied volatility continues to increase during the first 2 days of the year for all exchange rates, with the significant results reported for USD/EUR and especially USD/CHF, before declining between trading day +2 and trading day +10. The results support the hypothesis 17.

The finding that implied volatility tends to increase well before the turn of the year is consistent with Rogalski and Maloney (1989) and Jones and Singh (1997), but contradicts Barone – Adesi and Cyr (1994). Barone – Adesi and Cyr (1994) used weekly closing data, motivating this by the fact that the use of daily time series would result in numerous missing observations. However, the use of low frequency data affects the accuracy of the analysis. Consistent with Rogalski and Maloney (1989), we use daily implied volatility series. In spite of some inconsistencies in the results, we contribute to the existing literature by concluding that the FX implied volatility behaves similarly to the equity volatility prior to year end. A fall in the implied volatility reported for the period between trading day +2 and trading day +10 is also consistent with Rogalski and Maloney (1989), who suggested that turn of the year effect would be indicated by the increasing implied volatility as the turn of the year approaches, and declining implied volatility during and after the turn of the year. Rogalski and Maloney (1989) explained a fall in the implied volatility during and after the year-end by the declining ratio of the remaining number of high variance days to the total remaining days to expiration date. The main inconsistency with Rogalski and Maloney (1989) is that we observe a fall in the FX implied volatilities (which is statistically significant for USD/CHF only) after the second day of a year, while Rogalski and Maloney (1989) reported statistically significant fall in the stock implied volatility during the last two and the first ten trading days of a year. This finding could be explained by the fact that the seasonality patterns in the currency implied volatilities are relatively longer lived compared to those in other markets' volatilities. As the evidence, Ederington and Lee (2001) reported that implied volatility in the stock, bond and FX markets increases prior to the release of the scheduled announcements, but suggested that relative to other financial markets, implied volatility remains high much longer in the FX market before returning to the previous level.

The most obvious explanation for the turn of the year effect is Rogalski and Maloney's (1989) seasonal risk premium hypothesis. This hypothesis is consistent with the idea of the efficient option market that anticipates higher than average volatility around the turn of the year and incorporates this expectation into the market prices. The higher return variability anticipated by the market participants at the turn of the year is reflected in the prices of the options whose expiration dates fall in the following year, resulting in the increased implied volatilities. Another explanation for increased implied volatility before and during the turn of the year is the concentrated liquidity-trading hypothesis of Lakonishok and Smidt (1986)[17]. Lakonishok and Smidt (1986) argued that trading volume at the equity markets is abnormally high in late December and early January due to the year-end window dressing, which on its own causes an increased activity of the nondiscretionary liquidity traders (Admati and Pfeiderer, 1988)[18] in the FX market. The resulting concentration of informed traders prior to the turn of the year would make exchange rates more informative as well as more volatile. Our results suggest that consistent with Rogalski and Maloney's (1989) seasonal risk premium hypothesis and Admati and Pfeiderer's (1988) private information based trading model, which are not mutually exclusive, currency implied volatilities tend to raise during 30 days prior to the year-end and decline to the previous levels following the year-end.

Table 7-4 suggests that in both five year samples, implied volatility tends to increase during the last 30 and the first 2 days of a year with the results being slightly more significant for the sample period of 1994-1998. The regression coefficient $\beta_{i(-2)}$ is significant for USD/GBP, USD/CHF and USD/JPY in the pre euro sample, but significant for USD/EUR only in post euro period. Besides, the regression coefficient $\beta_{i(+2)}$ is significant at 1% significance level for USD/EUR, USD/GBP, and USD/CHF in the sample period of 1994-1998, but significant at 5% significance level for USD/CHF only in post euro period. A declining trend in turn of the year effect over time, which is another contribution to the existing literature on the volatility seasonality patterns, could be explained by Gu (2003), who argued that as seasonality anomalies became well known, more experienced and knowledgeable investors would reflect the January effect (that is a part of the turn of the year effect) in their trading. Therefore, the trading of these investors should diminish the anomaly.

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[17] The hypothesis is based on the private information hypothesis of Admati and Pfeiderer (1988), which as we suggested, explains Monday effect in the currency implied volatilities.
[18] As suggested by Admati and Pfeiderer (1988), because of the reduced transaction costs, increased liquidity trading attracts informed traders, who have the discretion to time trades so as to reduce the effect on price.

7.4. Holiday Effect in the FX Implied Volatilities

Table 7-5 suggests that there is a strong evidence of the holiday effect in the FX implied volatilities, which is consistent with the hypothesis 17. Implied volatility tends to decline immediately prior to the holiday, with the results being significant at 1% significance level for USD/EUR. A significant increase in the volatility is observed on a day immediately following the official holiday, with the statistically significant results reported for USD/EUR, USD/GBP and USD/CHF[19]. The results are not surprising as the expected future (realized) volatility should decline prior to the market inactivity caused by the holidays. The uncertainty is high following the holidays given that the market's expected (realized) future volatility increases again. The reason is that both private and public information accumulated during market close (or limited trading) could again be used to trade.

Copeland and Wang (1994) suggested that the FX markets are usually more active when a holiday is approaching with a greater variance caused by an increased amount of trading. Besides, as argued by Andersen and Bollerslev (1998), market activity declines significantly during the holidays. Such extreme slowdown in the market activity over holidays resembles the behavior of the volatility prior to and during the weekends. Consistent with the private information theories of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), a fall in the implied volatility prior to the holiday could also be explained by the traders' trading patterns and the increased selling pressure due to many traders closing their positions before the holiday.

The regression coefficients reported for the days following the holidays are positive and are statistically more significant than those denoting the days immediately preceding the holidays. The increased market activity following the holidays resembles the behavior of the volatility following the weekends. Consistent with Harvey and Whaley (1992), who explained high Monday volatility by the

[19] These findings suggest that the holiday effect, indicated by the reduced implied volatility prior to the holiday and increased implied volatility following the holiday (documented by Tanizaki (2004) for the Japanese equity index) exists in the FX market.

traders' trading patterns, significantly positive implied volatility change following the holidays could be explained by the traders reopening their positions after the holidays and the resulting buying pressure that causes the implied volatility to rise. A significant increase in the implied volatility following the holidays could be explained by the private information hypothesis of Admati and Pfeiderer (1988) and Foster and Viswanathan (1990), which explains increased implied volatility observed on Monday. Consistent with Foster and Viswanathan (1990), traders use private information accumulated during the holidays before the information is publicly disseminated, resulting in the positive and statistically significant implied volatility immediately after the holidays.

7.5. Turn of the Quarter Effect in the FX Implied Volatilities

We hypothesize that the quarterly patterns in the equity markets should drive calendar patterns in the FX markets. Barone-Adesi and Cyr (1994) showed that equity volatility has a tendency to be lower in the beginning of all quarters two through four than in the rest of a year. Financial reporting and financial statement disclosures as well as the associated FX transactions tend to concentrate around quarter ends, which explain quarterly patterns in the equity market and in our view, could drive quarterly patterns in the FX market. Table 7-6 suggests that there are no statistically significant quarterly patterns in the FX implied volatilities, rejecting the hypothesis 18. Although the implied volatility changes tend to be lower in the beginning of a quarter relative to the remainder of a quarter, only one[20] of the $\beta_{i(q)}$ regression coefficients is statistically significant at 10% significance level.

The results reported for five-year sample periods are similar to those reported for the entire period of 1994-2003, though estimates are more statistically significant in the post euro period, providing some support for the hypothesis 2. None of the pre euro $\beta_{i(q)}$ coefficients is statistically significant, while the equivalent post euro regression estimates reported for USD/EUR and USD/JPY are statistically significant. These results could potentially be explained by Arsad and Coutts (1997) and Steeley (2001), who suggested that the seasonality patterns at the financial markets are much less visible during periods of the market rises, but become significant during market falls. If the market direction explains the seasonality patterns in the asset return series, it is also likely to impact the patterns in the implied volatilities, which should become more sensitive to the calendar effects in a declining rather than a rising market. Therefore, the sample period of 1994-1998 would be associated with relatively weak seasonality patterns due to a strong USD in the 1990s, while post euro period characterized by the weakening dollar, would be associated with more obvious anomalies.

[20] the regression estimate $\beta_{i(q)}$ reported for USD/JPY is statistically significant at 5% significance level

7.6. Summary

This chapter focuses on the seasonality patterns in the FX implied volatilities. The seasonality patterns studied in this study are the day of the week effect, the turn of the year and the turn of the month effects, monthly and quarterly patterns and finally the holiday effect. We also differentiate between the period preceding and following the introduction of euro to study the impact of the euro introduction on the implied volatility seasonality patterns. Although there is some, though limited literature on the intraweek currency volatility patterns, the literature on other seasonality patterns in the FX implied volatilities is very limited, providing an opportunity to conduct an innovative piece of research.

We find a strong evidence of the day of the week effect in the FX implied volatilities, which has already been documented for the equity and currency futures implied volatilities by Harvey and Huang (1991) and Ederington and Lee (1996). The day of the week effect is indicated by the positive implied volatility changes on Monday and Tuesday and negative implied volatility changes on Thursday and Friday. The Monday regression coefficients are statistically significant for all exchange rates, while the coefficients for the remaining days are statistically significant for at least two exchange rates. We explained high Monday and Tuesday volatilities mainly by the private information hypothesis[21] of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) and relatively low Thursday and Friday implied volatilities by the announcements effect. Consistent with Muller et. al (1990), we conclude that volatility is low on weekends compared to the trading days, and tend to be higher on Sunday than on Saturday, due to a trading activity in some Middle Eastern markets, which are open on Sunday and early Monday morning activity in East Asian markets, which coincide with Sunday nights in GMT. Our most significant contribution to the existing literature is that the day of the week effect has become more obvious following the introduction of the euro. We try to

[21] Foster and Viswanathan (1990) argued that since traders use private information accumulated during the weekend before the information is publicly disseminated, volatility is significant on Monday. Although the FX is a 24 hour market, traders prefer trading when the liquidity is high (eg Monday).

explain this phenomena by the euro being more volatile currency than the DM (Heaney and Swieringa, 2003), the concentration of euro related announcements on Thursday and Friday, the strengthened impact of the private information based trading on the implied volatility (McGroarty et. al, 2005) and finally by the USD depreciation and the theory that seasonality patterns become more obvious in a declining rather than rising markets (Arsad and Coutts, 1997 and Steeley, 2001).

We also find an evidence of the strong turn of the year effect in the FX implied volatilities. The results suggest that the implied volatility tends to increase during the last 30 and the first 2 days of the year, before declining between trading +2 and +10. This behavior of the implied volatility around the turn of the year has already been documented at the equity markets by Rogalski and Tinic (1986) and Rogalski and Maloney (1989) and could be explained by Rogalski and Maloney's (1989) seasonal risk premium hypothesis and the concentrated liquidity-trading hypothesis by Lakonishok and Smidt (1986). Although a fall in the equity implied volatility starts two days prior to the year end (Rogalski and Maloney, 1989), we found FX implied volatility starting to decline only after two days following the turn of the year. This finding is a major contribution of this chapter and could be explained by the fact that the seasonality patterns in the currency implied volatilities, including the turn of the year effect, are relatively longer lived, compared to those in other markets' volatilities. We note that the turn of the year effect is more significant in the sample period preceding the introduction of euro and explain a declining trend in the turn of the year effect over time by the diminishing January effect in the financial markets.

We do not find a strong evidence of the monthly or quarterly patterns in the FX implied volatilities, noting that the quarterly patterns became more significant in the second sample period of 1999-2003, which could be due to USD depreciation and the fact that seasonality patterns are more obvious in the declining markets. We find that the FX implied volatility is positive and statistically significant for USD/CHF around the turn of a month, even after excluding year-ends, implying that there is some, though not very significant evidence of the turn of the month effect in the FX implied volatilities. Increased volatility around the turn of the month is explained by the substantial payments to private investors in the US economy and the fact that most corporate and municipal debt in the US is payable on the first and last days of the month, affecting USD volatility.

Finally, we report decreased implied volatility prior to and increased implied volatility following the holiday, confirming the fact that the holiday effect documented by Tanizaki (2004) for the Japanese equity index exists in the FX market. By hypothesizing that the market activity during and around the holidays resembles the behavior of the volatility prior to and around the weekends, we try to explain decreased implied volatility prior to the holidays by traders' trading patterns and the increased selling pressure due to many traders closing their positions before the holidays. Consistent with Foster and Viswanathan (1990), we explain a positive and statistically significant implied volatility change following the holidays by the traders using private information accumulated during the market inactivity before the information is publicly disseminated.

Table 7-1. Day of the Week Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0001	0.17	-0.0020	-0.77	-0.0030	-1.06	-0.0020	-1.16
V (lag)	-0.0320	-1.16	-0.2150	-3.26***	-0.2820	-7.58***	-0.0430	-1.28
MON	0.0100	3.77***	0.0150	3.66***	0.0230	3.46***	0.0060	1.69*
TUE	0.0001	-0.16	0.0140	2.48**	0.0090	2.32**	0.0010	0.27
THU	-0.0050	-2.02**	-0.0070	-1.97**	-0.0040	-1.15	-0.0020	-0.72
FRI	-0.0050	-2.17**	-0.0060	-1.78*	-0.0020	-0.56	-0.0010	-0.20
SAT	-0.0010	-0.53	-0.0040	-0.56	-0.0090	-1.65*	0.0020	0.67
SUN	-0.0020	-0.83	0.0070	1.30	0.0001	-0.12	0.0040	1.88*

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0010	-0.55	-0.0060	-1.06	-0.0080	-1.93*	-0.0020	-0.70
V (lag)	-0.0140	-0.35	-0.2170	-2.90***	-0.3010	-6.07***	-0.0030	-0.05
MON	0.0060	1.48	0.0140	1.36	0.0260	1.71*	-0.0020	-0.41
TUE	0.0000	-0.04	0.0240	2.24**	0.0160	2.48**	0.0020	0.40
THU	-0.0010	-0.31	-0.0040	-0.52	0.0001	0.05	-0.0020	-0.42
FRI	0.0010	0.25	-0.0040	-0.62	0.0020	0.28	0.0030	0.83
SAT	0.0040	0.62	-0.0090	-1.49			0.0160	1.51
SUN	-0.0060	-1.01					0.0190	2.07**

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0020	0.85	0.0010	0.23	0.0020	0.55	-0.0030	-1.00
V (lag)	-0.0670	-1.98**	-0.2020	-1.90*	-0.2450	-5.26***	-0.0920	-2.01**
MON	0.0130	4.18***	0.0130	3.56***	0.0190	2.49**	0.0130	3.20***
TUE	0.0001	-0.12	0.0060	1.71*	0.0020	0.58	0.0010	0.14
THU	-0.0090	-2.84***	-0.0100	-3.29***	-0.0090	-1.97**	-0.0020	-0.59
FRI	-0.0110	-3.37***	-0.0080	-1.86*	-0.0060	-1.37	-0.0040	-1.03
SAT	-0.0030	-1.19	-0.0060	-0.95	-0.0130	-2.38**	0.0010	0.33
SUN	-0.0030	-1.16	0.0040	0.84	-0.0050	-1.29	0.0040	1.29

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum\alpha_i V_{i,t-1} + \sum\beta_i M_{i,t} + \sum\gamma_i T_{i,t} + \sum\delta_i Th_{i,t} + \sum\eta_i F_{i,t} + \sum\theta_i S_{i,t} + \sum\lambda_i Sun_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;
$M_{i,t}$, $T_{i,t}$, $Th_{i,t}$, $F_{i,t}$, $S_{i,t}$, and $S_{i,t}$ are the dummy variables for Monday, Tuesday, Thursday, Friday, Saturday and Sunday at time t
ε_{it} is the error term; The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 7-2. Day of the Week Effect with the Announcements

1998-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0020	0.73	-0.0010	-0.30	0.0010	0.31	-0.0010	-0.40
V (lag)	-0.0260	-0.84	-0.1850	-1.94*	-0.2190	-5.03***	-0.0580	-1.11
MON(A)	0.0070	1.53	0.0130	1.56	0.0500	2.98***	-0.0010	-0.10
TUE(A)	-0.0050	-1.54	0.0060	1.63	0.0001	0.02	-0.0050	-1.21
THU(A)	-0.0070	-1.76*	-0.0070	-1.83*	-0.0090	-1.81*	-0.0050	-1.02
FRI(A)	-0.0130	-3.80***	-0.0100	-2.82***	-0.0040	-0.86	-0.0070	-1.83*
MON(N)	0.0120	3.98***	0.0150	4.21***	0.0120	1.60	0.0080	1.80*
TUE(N)	0.0020	0.37	0.0060	1.58	0.0030	0.52	0.0001	0.07
THU(N)	-0.0030	-0.80	-0.0050	-1.26	-0.0010	-0.18	0.0040	0.82
FRI(N)	-0.0060	-1.51	0.0010	0.21	-0.0050	-1.02	0.0010	0.13

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

TUE/WED/THU/FRI (A) – days of the week when at least one of the macroeconomic indicators listed in Table 5-8 is announced
TUE/WED/THU/FRI (N) – days of the week when none of the macroeconomic indicators listed in Table 5-8 is announced

The estimation is based on the following model:

$$\mathbf{V}_{i,t} = \alpha_0 + \sum\alpha_i \mathbf{V}_{i,t-1} + \sum\beta_{ia} \mathbf{M}_{i,t} \mathbf{D(a)}_i + \sum\beta_{in} \mathbf{M}_{i,t} \mathbf{D(n)}_i + \sum\gamma_{ia} \mathbf{T}_{i,t} \mathbf{D(a)}_i + \sum\gamma_{in} \mathbf{T}_{i,t} \mathbf{D(n)}_i + \sum\delta_{ia} \mathbf{Th}_{i,t} \mathbf{D(a)}_i + \sum\delta_{in} \mathbf{Th}_{i,t} \mathbf{D(n)}_i + \sum\eta_{ia} \mathbf{F}_{i,t} \mathbf{D(a)}_i + \sum\eta_{in} \mathbf{F}_{i,t} \mathbf{D(n)}_i + \sum\theta_i \mathbf{S}_{i,t} + \sum\lambda_i \mathbf{Sun}_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;
$M_{i,t}$, $T_{i,t}$, $Th_{i,t}$, $F_{i,t}$, $S_{i,t}$, and $S_{i,t}$ are the dummy variables for Monday, Tuesday, Thursday, Friday, Saturday and Sunday at time t
εt is the error term
D(a) is the dummy variable for the announcements days, while D(n) is the dummy variable for the non-announcements days

ε_{it} is the error term; The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 7-3. Intra-Monthly Patterns

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0000	-0.13	0.0001	-0.23	-0.0010	-1.08	-0.0010	-0.55
V (lag)	-0.0290	-1.08	-0.2070	-3.09***	-0.2770	-7.36***	-0.0400	-1.22
FH	-0.0010	-0.47	-0.0010	-0.67	0.0010	0.31	-0.0020	-1.25
Constant	-0.0010	-1.56	-0.0020	-1.41	-0.0030	-2.39**	-0.0020	-1.97**
V (lag)	-0.0300	-1.11	-0.2070	-3.08***	-0.2780	-7.39***	-0.0390	-1.19
TOM	0.0020	1.61	0.0020	0.66	0.0060	2.36**	0.0010	0.54
TOM****	0.0010	0.91	0.0020	0.63	0.0050	1.83*	0.0001	0.03

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0010	-0.72	-0.0010	-0.25	-0.0030	-1.04	-0.0010	-0.41
V (lag)	-0.0160	-0.40	-0.2130	-2.76***	-0.2950	-5.89***	-0.0050	-0.11
FH	0.0010	0.38	-0.0010	-0.19	0.0010	0.30	-0.0020	-0.83
Constant	-0.0010	-1.00	-0.0020	-0.75	-0.0050	-1.91*	-0.0020	-1.47
V (lag)	-0.0170	-0.42	-0.2130	-2.75***	-0.2960	-5.92***	-0.0040	-0.10
TOM	0.0020	0.98	0.0020	0.33	0.0080	1.74*	0.0020	0.63

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0010	0.54	0.0001	-0.02	-0.0010	-0.41	-0.0010	-0.35
V (lag)	-0.0490	-1.48	-0.1810	-1.67*	-0.2410	-5.02***	-0.0850	-1.93*
FH	-0.0020	-1.15	-0.0020	-0.88	0.0000	0.11	-0.0020	-0.91
Constant	-0.0010	-1.16	-0.0010	-1.29	-0.0020	-1.37	-0.0020	-1.20
V (lag)	-0.0500	-1.51	-0.1810	-1.67*	-0.2420	-5.05***	-0.0850	-1.91*
TOM	0.0020	1.31	0.0020	0.76	0.0040	1.47	0.0000	0.01

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level
TOM**** turn of the month effect excluding turn of the year

FH – the first fifteen business days in a month
TOM –either the first or the last five business days in any month

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_{i(fh)} D(FH)_{i,t} + \sum \beta_{i(tom)} D(TOM)_{i,t} + \varepsilon_{it}$$

where:
$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;
$D(FH)_{i,t}$ and $D(TOM)_{i,t}$ are the dummy variables for days during the first 15 days of any month and during the last and first 5 days of any months, respectively

ε_{it} is the error term; The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 7-4. Turn of the Year Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0001	-0.55	-0.0010	-0.98	-0.0010	-1.03	-0.0020	-2.041**
V (lag)	-0.0310	-1.17	-0.2070	-3.01***	-0.2780	-7.36***	-0.0410	-1.24
TOY (-60)	-0.0040	-1.87*	0.0010	0.29	-0.0060	-1.47	-0.0020	-0.81
TOY (-30)	0.0030	0.92	0.0040	0.81	0.0050	1.22	0.0020	0.57
TOY (-10)	0.0050	1.33	0.0040	0.63	0.0110	1.84*	0.0100	2.41**
TOY (-2)	0.0100	1.93*	0.0130	2.31**	0.0070	1.45	0.0060	1.11
TOY (+2)	0.0290	1.89*	0.0170	1.63	0.0260	2.86***	0.0120	1.22
TOY (+10)	-0.0050	-1.06	-0.0080	-1.76*	-0.0070	-1.02	-0.0050	-0.99

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0010	-0.44	-0.0020	-0.85	-0.0020	-1.05	-0.0020	-1.26
V (lag)	-0.0190	-0.47	-0.2150	-2.78***	-0.2960	-5.89***	-0.0060	-0.12
TOY (-60)	-0.0070	-1.85*	0.0020	0.29	-0.0100	-1.50	-0.0030	-0.89
TOY (-30)	0.0030	0.79	0.0170	1.58	0.0080	1.12	-0.0010	-0.21
TOY (-10)	0.0040	0.60	0.0120	0.76	0.0160	1.55	0.0120	1.41
TOY (-2)	0.0090	1.05	0.0180	1.87*	0.0110	2.68***	0.0080	1.96**
TOY (+2)	0.0240	5.32***	0.0210	4.60***	0.0210	9.31***	0.0070	0.49
TOY (+10)	0.0010	0.13	-0.0050	-0.51	0.0040	0.43	0.0010	-0.08

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0001	-0.27	0.0010	-0.49	0.0001	-0.30	-0.0020	-1.58
V (lag)	-0.0520	-1.57	-0.1810	-1.65*	-0.2420	-5.03***	-0.0870	-1.95*
TOY (-60)	-0.0030	-0.88	0.0001	0.06	-0.0040	-0.77	-0.0010	-0.29
TOY (-30)	0.0020	0.53	-0.0030	-0.98	0.0020	0.59	0.0030	1.04
TOY (-10)	0.0060	1.42	0.0001	0.02	0.0080	1.15	0.0090	2.52**
TOY (-2)	0.0110	1.78*	0.0090	1.31	0.0030	0.47	0.0060	0.58
TOY (+2)	0.0310	1.29	0.0150	1.26	0.0260	2.34**	0.0160	1.20
TOY (+10)	-0.0100	-2.31**	-0.0100	-2.49**	-0.0140	-1.47	-0.0080	-1.40

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

TOY (-60) – days between 60 and 30 trading days prior to the turn of the year
TOY (-30) – days between 30 and 10 trading days prior to the turn of the year
TOY (-10) – days between 10 and 2 trading days prior to the turn of the year
TOY (-2) – days between 2 trading days prior to and 2 trading days following the turn of the year
TOY (+2) – days between 2 and 10 trading days following the turn of the year
TOY (+10) – days between 10 and 30 trading days following the turn of the year

The estimation is based on the following model:

$$\mathbf{V}_{i,t} = \alpha_0 + \sum \alpha_i \mathbf{V}_{i,t-1} + \sum \beta_{i(-60)} \mathbf{D(-60)}_{i,t} + \sum \beta_{i(-30)} \mathbf{D(-30)}_{i,t} + \sum \beta_{i(-10)} \mathbf{D(-10)}_{i,t} + \sum \beta_{i(-2)} \mathbf{D(-2)}_{i,t} + \sum \beta_{i(+2)} \mathbf{D(+2)}_{i,t} + \sum \beta_{i(+10)} \mathbf{D(+10)}_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;
$D(-60)_{i,t}$, $D(-30)_{i,t}$, $D(-10)_{i,t}$, $D(-2)_{i,t}$, $D(+2)_{i,t}$, and $D(+10)_{i,t}$ are the dummy variables for days between 60 days prior to and 10 days after the turn of the year

ε_{it} is the error term; The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 7-5. Holiday Effect

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0001	-0.61	-0.0010	-0.68	-0.0010	-1.19	-0.0020	-2.79***
V (lag)	-0.0310	-1.19	-0.2090	-3.12***	-0.2790	-7.35***	-0.040	-1.21
PREH	-0.0080	-3.27***	-0.0080	-1.60	-0.0040	-1.30	0.0010	0.40
POSTH	0.0080	3.18***	0.0080	1.86*	0.0080	2.05**	0.0050	1.62

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	-0.0010	-0.48	-0.0010	-0.39	-0.0030	-1.32	-0.0030	-2.20**
V (lag)	-0.0160	-0.43	-0.2140	-2.79***	-0.2970	-5.86***	-0.0060	-0.12
PREH	-0.0070	-1.89*	-0.0070	-0.71	-0.0020	-0.32	0.0040	0.60
POSTH	0.0070	1.84*	0.0080	0.95	0.0130	1.84*	0.0080	1.64*

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0001	-0.32	-0.0010	-0.74	0.0001	-0.23	-0.0020	-1.61
V (lag)	-0.0540	-1.65*	-0.1860	-1.73*	-0.2420	-5.06***	-0.0850	-1.91*
PREH	-0.0090	-2.91***	-0.0080	-2.3**	-0.0060	-1.54	-0.0010	-0.23
POSTH	0.0090	2.73***	0.0080	1.96**	0.0040	0.96	0.0020	0.55

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

PREH –the days preceding official holidays in USA, Germany, UK, Switzerland and Japan
POSTH – the days following official holidays in USA, Germany, UK, Switzerland and Japan

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_{i(h-)} H-_{i,t} + \sum \beta_{i(h+)} H+_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;
$H-_{i,t}$ and $H+_{i,t}$ are the dummy variable for days preceding and following official holidays in USA, Germany, UK, Switzerland and Japan. Dummy variables denote working days only, so if the holiday occurs on Friday, the dummy variable denoting the day following the holiday takes the value of one on the following Monday instead of Saturday.

ε_{it} is the error term; The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 7-6. Quarterly Patterns

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0001	-0.21	-0.0010	-0.40	-0.0010	-1.03	-0.0010	-1.08
V (lag)	-0.0300	-1.09	-0.2070	-3.09**	-0.2770	-7.36***	-0.0420	-1.25
Q	-0.0020	-1.23	-0.0040	-1.36	0.0001	-0.01	-0.0070	-2.30**

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0001	-0.44	-0.0010	-0.25	-0.0020	-0.86	-0.0010	-0.90
V (lag)	-0.0160	-0.41	-0.2130	-2.76***	-0.2950	-5.90***	-0.0060	-0.13
Q	-0.0010	-0.23	-0.0040	-0.67	-0.0020	-0.34	-0.0050	-1.06

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
Constant	0.0001	0.18	0.0001	-0.37	-0.0010	-0.61	-0.0010	-0.58
V (lag)	-0.0500	-1.49	-0.1820	-1.68*	-0.2410	-5.02***	-0.0880	-1.99**
Q	-0.0040	-1.85*	-0.0040	-1.43	0.0020	0.58	-0.0080	-2.49**

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

Q – the first fifteen business days of any quarter two through four

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_{i(q)} Q_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;
$Q_{i,t}$ is the dummy variable for days during the first 15 days of the quarter two through four

ε_{it} is the error term; The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

CHAPTER 8. RELATION BETWEEN FX RETURNS AND IMPLIED VOLATILITIES (EMPIRICAL)

A number of recent papers have examined the return - implied volatility relation. However the literature on the relation between financial asset returns and volatility is limited to equity markets with only a few on foreign exchange (FX) mainly focusing on FX futures. This chapter focuses on the relation between FX returns and implied volatilities, by covering three main areas: (a) the contemporaneous relation between FX returns and implied volatilities, (b) the asymmetric feature of this relation and finally (c) the ability of the FX implied volatility to predict future returns.

We provide evidence of a strong relation between implied volatility and contemporaneous returns[1], which contradicts the results of the prior studies on the equity markets, but supports the findings on the FX futures volatility–return relation. We contribute to the existing literature, by observing this relation to decline in significance post Euro and explain this by the increased uncertainty, indicated by higher standard deviation of the implied volatility. Finally, both large appreciation and depreciation of US dollar against foreign currencies was found to cause a significant increase in FX market uncertainty. In light of these results, which contradict existing findings on the equity markets, we conclude that this result could be due to structural differences between equity and FX markets. Contrary to the existing literature on the stock market but consistent with the findings on the FX market, no evidence of the asymmetric impact[2] of the implied volatility on the FX returns is found. However, as a contribution to the literature, we observe the stronger impact of small returns (relative to larger returns) in the high volatility environment following the introduction of Euro.

We also investigate the impact of news announcements on the FX returns and implied volatilities and find the relation between the magnitude of the returns and implied volatilities to be statistically more significant on non-announcement days. We find that

[1] The relation is significantly positive for USD/EUR, USD/CHF and USD/JPY, and significantly negative for USD/GBP

[2] The results indicate that both positive and negative FX returns are associated with the increased implied volatility, while the impact of small returns is found to be stronger than the impact of large returns, albeit the evidence is not significant enough to suggest that the relation is asymmetric.

both the appreciation and depreciation of USD against foreign currencies on non-announcement days is associated with the significant rise in the implied volatility, with no significant results reported for the announcement days[3].

Although no strong evidence of the relation between FX market implied volatilities and the forward looking returns is found, we note that the increase in the FX market volatility is associated with the depreciation of US Dollar in pre-Euro, and with the appreciation of USD in the post-Euro period. This could be due to the currency appreciation/depreciation expectation driven by the interest rate differentials. The relation becomes more significant when only extreme levels of the implied volatility are considered. Finally, as the contribution to the literature, we find that the impact of the extreme levels of the implied volatility on the forward looking returns is particularly significant for negative (as opposed to positive) returns and for extremely large increases (as opposed to decreases) in the level of the implied volatility.

Section 8.1 is dedicated to the relation between FX contemporaneous returns and implied volatilities, while section 8.2 focuses on the asymmetric feature of this relation. Section 8.3 examines the relation between FX forward looking returns and implied volatilities. We conduct robustness checks in section 8.4 and provide a brief summary of the chapter in section 8.5.

[3] These results could be explained by the fact that the important news announcements lead to the fall in the implied volatility significantly affecting the volatility – return relation on announcement days.

8.1. Relation Between Contemporaneous Returns and Implied Volatilities

Table 8-1 reports the estimation results of Equation 4-17, providing an evidence of the significant relation between daily implied volatility changes and underlying contemporaneous exchange rate returns (hypothesis 19). For the full sample period, the signs of the coefficients for USD/EUR, USD/CHF and USD/JPY are positive, implying that as the FX rates move up the implied volatility follows the trend. The appreciation of the EUR, CHF and JPY against US dollar is associated with the increase in the market uncertainty, but the opposite is true for the USD/GBP. The results could be caused by the fact that over the sample period, the market expected USD appreciation against EUR, CHF and JPY and USD depreciation against GBP[4]. The movement of the FX rates in the opposite direction tends to cause uncertainty and therefore increases implied volatility. These results contradict Bollerslev et al., (2006) but are consistent with the findings by Kim and Kim (2004) for currency futures.[5]

Table 8-1 shows the regression coefficients are less significant in 1999-2003 than in 1994-1998 for USD/EUR, USD/GBP and USD/CHF. We note that the standard deviation of the implied volatility series (volatility of volatility) tends to be significantly higher in the sample period 1999-2003, suggesting that uncertainty increased with the introduction of euro. The increased volatility was predicted by Masson and Turtelboom (1997) amongst others, who explained higher volatility by the European Central Bank's focus on price stability and the exclusion of lender of last resort responsibilities. The standard deviation of the FX return series also tends to be higher in 1999-2003 sub sample for all FX rates, apart from USD/EUR, but the difference is not statistically significant. This finding supports the results in Chaboud and Weinberg (2002)[6] and could be explained by the fact that FX rates are more volatile when fluctuations in the economic outlook across national economies are greater (see Stock and Watson, 2003). Therefore, the decreased significance of the implied volatility return relation in post Euro period could be explained by the fact that the

[4] Interest rates in US were higher than those in Europe, Switzerland and Japan and lower than the UK rates in the sample period

[5] However the significance of the regression coefficient for USD/EUR contradicts Kim and Kim (2004) findings as they did not find any significant relation between USD/DEM returns and implied volatility.

[6] Using high-frequency data to examine FX market historical volatility, Chaboud and Weinberg (2002) found that the daily and intraday volatilities have not changed appreciably after the introduction of Euro.

increased market uncertainty following the introduction of Euro does not appear to significantly impact the historical (realized) volatility of the FX return series. In other words, the introduction of euro increased the investors' expectations of market uncertainty, but did not significantly affect the investors' reactions in response to Euro.

All *R(ABS)* coefficients are positive and significant at 1% significance level in both five year periods, implying that the magnitude of the FX market movements, regardless of their direction, is positively related to the implied volatility changes (hypothesis 21). This finding indicates that the magnitude of the FX market movements, regardless of their direction, is positively related to the implied volatility changes. In other words, consistent with Kim and Kim (2004), we conclude that both large appreciation and depreciation of US dollar against foreign currencies result in the market participants expecting higher future volatility. Given that Giot (2003) did not find any strong relation between the size of the US stock index returns and implied volatility changes an important implication of this study could be that the relation between volatility and asset returns at the FX market is different from that at the equity market. In other words, participants in the FX market would form the expected future volatility in different ways from those in equity and bond markets and/or this difference could be due structural differences between the two markets (including liquidity, transactions costs and use of derivatives in the FX market). Finally, Table 7 shows the regression coefficient on the relation between contemporaneous and lagged volatility changes is negative for all FX rates. This result implies mean reversion in implied volatilities and confirms the existing findings on the equity market and Treasury Bonds. The mean reversion feature of the implied volatility is stronger in 1994-1998 period for USD/GBP and USD/CHF and in 1999-2003 period for USD/JPY.[7]

[7] A negative relation between contemporaneous and lagged implied volatility changes could be due to the measurement error in the implied volatility (see Jorion, 1995 and Ederington and Lee, 1996).

8.2. Asymmetric Feature of the Return – Volatility Relation

We study the asymmetric feature of the relation between currency market volatility and the underlying FX returns by differentiating between (1) small and large, (2) positive and negative returns and (3) announcement and non-announcement day. We hypothesize that the relation could be asymmetric in terms of both size and sign of the returns. Bad news should become more important in the good times when economy is doing well, while positive news should have more significant impact on the FX implied volatility during recession. In terms of the size of the returns, from one side, large returns could indicate shocks associated with the increased uncertainty that could lead to a stronger return – implied volatility relation. From another side, since large movements in the FX rates tend to occur in the market environment characterized by relatively high uncertainty, option traders do not react to large returns as aggressively as they do to small returns. Finally, announcements are associated with the reduced implied volatility, therefore we expect that an increase in the implied volatility following the USD appreciation and depreciation (if any) to be smaller on the announcement days. In section 8.2.1 (8.2.2), we discuss the impact of positive and negative (small and large) returns on the FX implied volatility. Finally, in section 8.2.3, we focus on the return – volatility relation on the announcement and non-announcement days.

8.2.1. Positive versus Negative Returns

The estimation results for positive and negative returns are reported in Table 8-2. The combined lagged effect is negative for all exchange rates, but several coefficients are insignificant[8]. The regression coefficients are significant for all exchange rates and in both sub-periods, except for negative USD/CHF returns in 1994-1998 and negative USD/JPY returns in 1999-2003 period. In spite of the evidence of the asymmetric relation between stock market volatility and returns documented in the existing literature (Fleming et. al, 1995, Dumas et. al, 1998 and Giot, 2003), the estimation results for the positive and negative returns presented in Table 8-2 reject hypothesis 22 as the response of the implied volatility at the FX market is not asymmetric. In other words, both increase and decrease in

[8] Similar results have been reported by Davidson et. al (2001) for the currency futures.

the FX rates (both appreciation and depreciation of US dollar) are associated with the increase in the FX implied volatility[9]. Although the results contradict the findings on the stock market, they are consistent with the empirical studies on the relation between return and volatility of the FX futures (Kim and Kim, 2004).

The main area where these results contradict prior existing literature on the relation between FX returns and volatility is the impact of implied volatility on the DM (Euro) returns. Fung and Hsieh (1991) and Kim and Kim (2004) found the magnitude of the implied volatility responses to positive and negative movements in DM future prices to be statistically the same (insignificant contemporaneous coefficient). However, our estimation results for 1994-2003 suggest that the implied volatility response to the positive USD/EUR returns is significantly stronger than the response to the negative returns, resulting in positive and statistically significant contemporaneous return–implied volatility relation. The difference in findings could be explained by the use by Fung and Hsieh (1991) and Kim and Kim (2004) of volatilities implied from the options on futures contracts and the use of the volatilities implied from the options on the FX rates[10] for a more recent sample period in this chapter. Besides, our sample period is associated with the relatively larger proportion of bad news leading to the USD depreciation, coinciding with the period of late 1990s and early years of this decade characterised by the increased amount of the negative macroeconomic news in the US. Given that the implied volatility is persistent and is typically higher after the release of the bad news than after the announcement of the good news, the impact of the positive USD/EUR returns, denoting USD depreciation, on the USD/EUR implied volatility is likely to be statistically stronger than the impact of the negative USD/EUR returns.

8.2.2. Large versus Small Returns

The results in Table 8-3 suggest that the impact of both large and small returns on FX implied volatility is statistically significant for all FX rates (except for large USD/CHF

[9] We note that there is a material difference in the magnitude of the coefficients reported for positive and negative returns resulting in the statistically significant coefficients in the regression model 4-17
[10] The use of the cash implied volatilities in our study helps to avoid the problem of thin trading and non-trading effect, which arises when volatilities implied from the options on the futures markets are used and is caused by the lack of trading during particular times of a day or a week.

returns). The sign of the regression coefficients for both large and small FX returns is positive, with the exception of large USD/GBP returns. Therefore, it appears that large and small appreciation and depreciation of USD are associated with the increased implied volatility, but the negative relation between USD/GBP returns and implied volatility is driven by particularly large returns. Malz (2001) argues that this result could potentially be explained by relatively significant number of large returns in the data sample or relatively significant number of large returns with the negative sign. However, the detailed analysis of data suggests that this explanation is not true (less than 18% of the returns are large and only 10% of the returns are large and negative).

Although there is a little evidence of the statistically significant asymmetric impact of large compared to small FX returns on the implied volatility rejecting hypothesis 22, the impact of small returns on the market volatility is more significant than the impact of large returns for all FX rates (except USD/JPY). This result could be explained by the behavior of option traders, who tend to react aggressively to the movements in the FX rates when normal market conditions prevail by strongly bidding up implied volatility, but are reluctant to do so in the uncertain market conditions. Since large movements in the FX rates tend to occur in the market environment characterized by relatively high uncertainty, option traders do not react to large returns as aggressively as they do to small returns. Given that this phenomenon is more obvious in 1999–2003 period, it appears that the increased uncertainty (indicated by higher volatility of volatility) following the introduction of Euro makes option traders even more reluctant to trade in the uncertain market conditions characterized by large movements in the FX rates.

8.2.3. Announcement versus Non-Announcement Days

Table 8-4 analyses the FX return-implied volatility relation on both news- and non-news-announcement days and provides support for hypothesis 23. For all the FX rates, apart from USD/EUR, the relation between FX contemporaneous returns and implied volatilities on non-announcement days is positive and statistically significant for USD/JPY and USD/CHF. However, for announcement days, the FX return–implied volatility relation is positive for USD/EUR and USD/JPY, and negative for USD/GBP and USD/CHF (the results are significant for USD/EUR and USD/CHF). The results do not suggest that the relation between FX returns and implied volatilities is affected by the macro announcements. However, the relation between daily implied volatility changes and the magnitude of the FX returns is positive and statistically significant on non announcement days, and statistically insignificant on the announcement days. The results imply that both the appreciation and depreciation of USD against foreign currencies on non-announcement days is associated with a significant rise in the implied volatility. When non-announcement days are excluded from the sample, none of the relations is statistically significant. A big move in the FX rate on non-announcement days result in the increased uncertainty as traders expect further large moves and therefore higher implied volatility. However, on the announcement days, the expected rise in the volatility resulting from the USD depreciation tend to be offset by the fall in the implied volatility caused by the release of the important news announcements, as traders link large moves in the FX rates to the news release.

8.3. Relation Between Forward Looking Returns and Implied Volatilities

Table 8-5 suggests that there is no statistically significant relation between implied volatility series and forward looking returns in the FX market, rejecting the hypothesis 24[11]. However, there is a consistency among the FX rates in terms of the sign of the regression coefficients in pre and post Euro periods (the relation is positive for all the FX rates in 1994 – 1998 period, but is negative for three out of four FX rates in 1999 – 2003 period). In other words, an increase in the FX market volatility is associated with the USD depreciation in pre-Euro period, but with the appreciation of USD in the period following the introduction of Euro. The practical interpretation of these results is that prior to the introduction of Euro, the market participants perceived market uncertainty indicated by the increased implied volatility as the signal for selling the dollar. This could potentially be explained by the fact that the market expected a USD appreciation given relatively higher US interest rates and the rising US economy. Not surprisingly, the most significant coefficient explaining the relation between implied volatility and forward looking price changes in 1994 -1998 period is obtained for USD/CHF.[12] However, since 1999 as indicated by the regression estimates market uncertainty has been perceived as the signal for buying the dollar. Again, it appears the market expected USD depreciation, which could be explained by the recession of 2001-2003 and the expectations of the interest rate cut. The FX rate of USD/CHF is the only currency pair, for which the relation between implied volatilities and future price changes remained positive (consistent with the existing empirical studies on the relation between stock market implied volatility and equity returns).

Table 8-6 shows there is no strong evidence in support of the hypothesis 25 that extreme levels of the implied volatility have an ability to predict future large returns. However, we note that the regression estimates in Table 8-6 are statistically more significant than those reported in Table 8-5, suggesting that the extreme levels of the implied volatility have more significant predictive power than the entire population of the

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[11] Only in the sub-period of 1999 – 2003, the null hypothesis of no relation between implied volatility and next day USD/GBP returns can be rejected.

[12] Historically, Swiss Franc has been regarded as a "safe heaven" currency, because of investors' preference to invest in Swiss Franc during uncertain market conditions and especially during the time of uncertainty around USD.

implied volatility series. This conclusion is consistent with the findings in the existing literature on the equity (Giot, 2003) and currency (Malz, 2000) markets.

There are some consistencies in our results for the FX future return-implied volatility relation. First, the predictive power of particularly large increases in the implied volatility is more statistically significant than that of extremely large volatility dips (consistent with Koulakiotis et. al, 2006[13]). Second, the ability of the implied volatility spikes to predict FX returns is stronger for negative returns than for positive returns for all the currency pairs, except USD/CHF (statistically significant for USD/JPY).[14] A possible explanation is that high implied volatilities coincide with increased risk aversion and with the market participants buying options in the uncertain time periods. Given the importance of USD in the world economy, the demand for the FX options would increase if the market experienced USD depreciation. As option traders start buying options to protect themselves against dollar depreciation, implied volatility tends to rise. If this activity occurs frequently, and the USD does not in fact depreciate as frequently, implied volatility will appear to be a poor predictor of the positive FX returns - USD depreciation (see Malz, 2001).

[13] Koulakiotis et. al (2006) suggested that the negative and positive sign of the conditional variance allowed the stock price returns to respond asymmetrically to rises and falls in the stock prices.

[14] This asymmetry might potentially be explained by the actual distribution of large-magnitude returns. In other words, extremely large USD/JPY jumps could predict negative USD/JPY returns better than they do negative returns simply because there are more negative returns in the sample. However, the number of positive USD/JPY returns tends to exceed the number of negative returns in the sample, suggesting that the distribution of large magnitude returns is not the explanation for the observed asymmetry.

8.4. Robustness Checks

In order to investigate the robustness of our results five further checks were carried out. The first considers the choice of the transformation method – the relation between FX returns and volatility is examined using discrete rather than lognormal (continuously compounded) changes in implied volatilities and the FX rates. The new regression estimates do not change our results significantly. The second issue concerns the uniformity of the results over various subsamples therefore we reexamine the results for subsamples of one year in length for both periods preceding and following the introduction of Euro. There is no significant change in the regression coefficient estimates implying that the results of this chapter are robust in the subsamples. Thirdly, we re-examine the regressions without the outliers and find the results are not significantly affected by their exclusion.[15] Fourthly, the relation between FX returns and implied volatility is examined after controlling for additional variables related to the business cycle fluctuations. The variables used in this study are the dummy variables indicating the state of the business cycle (e.g. high, moderate and low) based on the GDP growth rate and 3 months US Treasury yields. The inclusion of the additional variables into the regression estimation models does not change the results (confirming Ghysels et. al, 2005). Finally, the t-statistics are adjusted for heteroscedasticity and autocorrelation and our conclusions remain the same.

[15] Outliers are defined as those exceeding 2.33 standard deviations (0.99th percentile) or 3.09 standard deviations (0.999th percentile) in magnitude.

8.5. Summary

This study focuses on the relation between FX returns and implied volatilities, by covering three main areas: (a) the contemporaneous relation between FX returns and implied volatilities, (b) the asymmetric feature of this relation and finally (c) the ability of the FX implied volatility to predict future returns. The results are robust for heteroscedasticity and autocorrelation, do not change in subsamples and when discrete, rather than log normal changes in the variables are used, and are not affected by the inclusion of other variables or the exclusion of the outliers.

We provide evidence of a strong relation between implied volatility and contemporaneous returns, which is significantly positive for USD/EUR, USD/CHF and USD/JPY, and significantly negative for USD/GBP. The positive results for three out of four FX rates contradict prior studies on the relation between stock market contemporaneous returns and volatilities. However, this result supports the findings on the FX futures volatility–return relation. In addition, our sample period examined allows comparison between pre and post Euro periods and we find that the relation between contemporaneous returns and market volatility has declined in significance post Euro. This finding could be explained by the fact that the introduction of Euro resulted in increased uncertainty, indicated by higher standard deviation of the implied volatility in post Euro sample period. However it did not cause significant movements in the FX rates as the standard deviation of returns is unchanged. Finally, both large appreciation and depreciation of US dollar against foreign currencies was found to cause a significant increase in FX market uncertainty. In light of these results, which contradict existing findings on the equity markets, we conclude that this result could be due to structural differences between the two markets (including liquidity, transactions costs and use of derivatives) and/or participants in the FX market forming the expected future volatility in different ways from those in equity markets.

Contrary to the existing literature on the stock market but consistent with the findings on the FX market no evidence of the asymmetric impact of the implied volatility on the FX returns is found. In addition, the results indicate that both positive and negative

FX returns are associated with the increased implied volatility. The impact of small returns is found to be stronger than the impact of large returns, albeit the evidence is not significant enough to suggest that the relation is asymmetric. The stronger impact of small returns, which is more obvious in 1999 – 2003 sub-period could be explained by the behavior of the option traders. The traders tend to react aggressively to the movements in the FX rates when normal market conditions prevail by strongly bidding up implied volatility, but are reluctant to do so in the uncertain market conditions, associated with the extreme movements in the FX rates. As evidence, we observe the asymmetric impact of small and large returns on the FX implied volatility to be more significant in the high volatility environment following the introduction of Euro.

We also investigate the impact of news announcements on the FX returns and implied volatilities and find the relation between the magnitude of the returns and implied volatilities to be statistically more significant on non-announcement days. We find that both the appreciation and depreciation of USD against foreign currencies on non-announcement days is associated with the significant rise in the implied volatility, with no significant results reported for the announcement days. The rise in the implied volatility, resulting from the USD depreciation is obvious in the sample excluding the announcement days, but is offset by the fall in the implied volatility resulting from the release of the important news announcements.

Although no strong evidence of the relation between FX market implied volatilities and the forward looking returns is found, we note that the increase in the FX market volatility is associated with the depreciation of US Dollar in pre-Euro, and with the appreciation of USD in the post-Euro period. In other words, the market expected USD appreciation (uncertainty as proxied by the implied volatility increased during the periods when USD depreciated) in pre euro period and USD depreciation (implied volatility increased during the periods when USD appreciated) post euro. This could be explained by the fact that US had the highest interest rates among the home countries for the currencies covered by our study (apart from thee UK) in 1994-1999 sample, while the recession of 2001-2003 created the expectation (and later led to) of the interest rate cuts (Fed rate was cut from 6% to about 1%). The relation becomes more significant when only extreme levels of the implied volatility are considered. Finally, as the contribution to the literature, we find that the impact of the extreme levels of the implied volatility on the forward looking returns is particularly significant for negative (as opposed to positive) returns and for extremely large increases (as opposed to decreases) in the level of the implied volatility.

In this chapter we have studied the relation between FX implied volatility and returns by taking into account factors, such as announcement effect, size, direction and magnitude of the returns. However, there are also other factors that impact implied volatility. For example, there is a substantial literature on the seasonality patterns in the financial market implied volatility, such as the day of the week effect or intraday patterns. By taking into account such seasonality patterns into account, one could better explain return – volatility relation and future research on the relation between FX returns and implied volatility could consider this possibility.

Table 8-1. Relation Between Contemporaneous Returns and Implied Volatilities

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β_i	t-stats	β_i	t-stats	B_i	t-stats	β_i	t-stats
Constant	-0.0126	-11.80***	-0.0106	-5.30***	-0.0072	-3.66***	-0.0150	-11.60***
V (lag)	-0.0268	-1.43	-0.2477	-12.80***	-0.2592	-13.60***	-0.0621	-3.37***
R	0.0076	6.32***	-0.0111	-4.00***	0.0032	1.73*	0.0153	12.30***
R(ABS)	0.0284	15.90***	0.0283	6.83***	0.0149	5.36***	0.0257	14.80***

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β_i	t-stats	β_i	t-stats	B_i	t-stats	β_i	t-stats
Constant	-0.0119	-7.41***	-0.0133	-3.39***	-0.0088	-2.73***	-0.0154	-7.81***
V (lag)	-0.0296	-1.09	-0.2786	-9.89***	-0.2823	-10.50***	-0.0201	-0.74
R	0.0098	4.90***	-0.0175	-3.10***	0.0084	2.67***	0.0112	6.38***
R(ABS)	0.0302	10.70***	0.0363	4.45***	0.0162	3.58***	0.0239	9.91***

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	β_i	t-stats	β_i	t-stats	B_i	t-stats	β_i	t-stats
Constant	-0.0133	-9.54***	-0.0077	-5.12***	-0.0052	-2.30**	-0.0169	-9.81***
V (lag)	-0.0261	-1.00	-0.0549	-2.00**	-0.2082	-7.45***	-0.1070	-4.29***
R	0.0059	4.08***	-0.0049	-2.43**	-0.0017	-0.80	0.0220	12.30***
R(ABS)	0.0273	12.20***	0.0201	6.55***	0.0128	3.90***	0.0323	12.30***

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

V(LAG): relation between contemporaneous and lagged volatility changes
R: the relation between daily implied volatility changes and the contemporaneous FX returns
R(ABS): the relation between daily implied volatility changes and the magnitude of the FX returns

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_i R_{i,t} + \sum \gamma_i R(ABS)_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;
$R_{i,t}$ is logarithmic change in the spot price movement of the exchange rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the closing value of the exchange rate i on day t, while P_{t-1} denotes the closing value of the exchange rate i on day $t-1$;
$R(ABS)_{i,t}$ is absolute value of the daily rate of return $R_{i,t}$ of the exchange rate i on day t; and
ε_{it} is the error term

The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 8-2. Asymmetric Relation Between Contemporaneous Returns and Implied Volatilities (Positive vs. Negative Returns)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	B*i*	t-stats	βi	t-stats
Constant	-0.0065	-1.32	-0.0118	-1.47	0.0019	0.21	-0.0027	-0.427
V (lag)	-0.0258	-1.38	-0.2478	-12.80***	-0.2581	-13.50***	-0.0612	-3.33***
R(P)	0.0341	14.20***	0.0187	3.13***	0.0199	5.25***	0.0417	19.00***
R(N)	-0.0238	-8.84***	-0.0377	-6.33***	-0.0106	-2.54**	-0.0107	-3.78***

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	B*i*	t-stats	βi	t-stats
Constant	-0.0033	-0.538	-0.0179	-1.17	0.0000	0.0022	-0.0137	-1.29
V (lag)	-0.0284	-1.05	-0.2791	-9.90***	-0.2808	-10.40***	-0.0200	-0.74
R(P)	0.0394	10.40***	0.0231	1.93*	0.0276	4.61***	0.0334	11.80***
R(N)	-0.0228	-5.26***	-0.0488	-4.2***	-0.0046	-0.67	-0.0159	-3.90***

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	B*i*	t-stats	βi	t-stats
Constant	-0.0152	-1.75*	-0.0034	-0.54	0.0037	0.41	0.0041	0.54
V (lag)	-0.0261	-1.00	-0.0539	-1.96*	-0.2064	-7.37***	-0.1000	-4.03***
R(P)	0.0298	9.82***	0.0151	3.43***	0.0105	2.29**	0.0616	16.70***
R(N)	-0.0249	-7.44***	-0.0260	-5.84***	-0.0164	-3.39***	-0.0047	-1.22

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

V(LAG): relation between contemporaneous and lagged volatility changes
R(P): the relation between daily implied volatility changes and positive contemporaneous FX returns
R(N): the relation between daily implied volatility changes and negative contemporaneous FX returns

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \alpha_{i-} D(-)_t + \sum \alpha_{i+} D(+)_{i+} + \sum \beta_{i-} R_{i,t} D(-)_i + \sum \beta_{i+} R_{i,t} D(+)_i + \varepsilon_{it}$$

where:
$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate *i* on day *t*, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate *i* on day *t*, while IV_{t-1} denotes the daily implied volatility of the exchange rate *i* on day *t-1*;
$R_{i,t}$ is logarithmic change in the spot price movement of the exchange rate *i* on day *t*, equal to ln (Pt/Pt-1), where P_t denotes the closing value of the exchange rate *i* on day *t*, while P_{t-1} denotes the closing value of the exchange rate *i* on day *t-1*;
D(-) is a dummy variable that is equal to one when $R_{i,t}$ is negative and zero otherwise;
D(+) is a dummy variable that is equal to one when $R_{i,t}$ is positive and zero otherwise; and
ε_{it} is the error term

The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 8-3. Asymmetric Relation Between Contemporaneous Returns and Implied Volatilities (Large vs. Small Returns)

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0060	3.02***	-0.0059	-3.73***	0.0001	0.04	-0.0074	-3.76***
V (lag)	-0.0231	-1.22	-0.2453	-12.70***	-0.2590	-13.6***	-0.0597	-3.23***
R(L)	0.0066	4.87***	-0.0101	-3.25***	0.0039	1.88*	0.0186	12.70***
R(S)	0.0090	7.08***	0.0182	4.32***	0.0062	3.73***	0.0023	4.00***

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0127	3.92***	-0.0076	-2.46**	-0.0043	-1.67*	-0.0077	-2.39**
V (lag)	-0.0222	-0.81	-0.2773	-9.82***	-0.2838	-10.60***	-0.0184	-0.68
R(L)	0.0099	4.28***	-0.0151	-2.38**	0.0101	2.88***	0.0138	6.62***
R(S)	0.0065	3.49***	0.0146	1.93*	0.0063	2.70***	0.0023	3.21***

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0007	0.26	-0.0076	-2.52**	-0.0026	-1.46	-0.0086	-3.55***
V (lag)	-0.0220	-0.84	-0.0509	-1.86*	-0.2061	-7.37***	-0.1080	-4.33***
R(L)	0.0044	2.71***	-0.0048	-2.16**	-0.0019	-0.79	0.0265	13.00***
R(S)	0.0117	6.66***	0.0201	5.82***	0.0051	2.01**	0.0101	6.41***

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

V(LAG): relation between contemporaneous and lagged volatility changes
R(L): the relation between daily implied volatility changes and large (larger than one standard deviation from the mean) contemporaneous FX returns
R(S): the relation between daily implied volatility changes and small (smaller than one standard deviation from the mean) contemporaneous FX returns

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \alpha_{il} D(L)_l + \sum \alpha_{is} D(S)_{i+} + \sum \beta_{il} R_{i,t} D(L)_i + \sum \beta_{is} R_{i,t} D(S)_i + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$R_{i,t}$ is logarithmic change in the spot price movement of the exchange rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the closing value of the exchange rate i on day t, while P_{t-1} denotes the closing value of the exchange rate i on day $t-1$;

D(L) is a dummy variable that is equal to one when $R_{i,t}$ is larger than one standard deviation from the mean and zero otherwise;

D(S) is a dummy variable that is equal to one when $R_{i,t}$ is within one standard deviation from the mean and zero otherwise; and

ε_{it} is the error term

The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 8-4. Asymmetric Relation Between Contemporaneous Returns and Implied Volatilities (Announcement vs. Non-announcement Days)

1998-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	-0.0061	-5.58***	-0.0055	-4.37***	-0.0036	-2.01**	-0.0083	-5.58***
V (lag)	-0.0135	-0.52	-0.0368	-1.49	-0.2168	-7.57***	-0.0720	-2.86***
R(A)	0.0094	3.72***	-0.0027	-0.83	-0.0056	-1.66*	0.0026	0.95
R_{ABS}(A)	-0.0027	-0.98	0.0022	0.62	-0.0026	-0.70	0.0001	0.04
R(NA)	-0.0007	-0.45	0.0015	0.53	0.0049	1.90*	0.0214	8.04***
R_{ABS}(NA)	0.0166	11.10***	0.0174	5.96***	0.0146	5.49***	0.0232	8.13***

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

V(LAG): relation between contemporaneous and lagged volatility changes
R(A): the relation between daily implied volatility changes and the contemporaneous FX returns on the announcement days (days when at least one of the macroeconomic indicators listed in Table 5-8 is announced)
R_{ABS}(A): the relation between daily implied volatility changes and the magnitude of the FX returns on the announcement days (days when at least one of the macroeconomic indicators listed in Table 5-8 is announced)
R(A): the relation between daily implied volatility changes and the contemporaneous FX returns on the non-announcement days (days when none of the macroeconomic indicators listed in Table 5-8 is announced)
R_{ABS}(A): the relation between daily implied volatility changes and the magnitude of the FX returns on the non announcement days (days when none of the macroeconomic indicators listed in Table 5-8 is announced)

The estimation is based on the following model:

$$V_{i,t} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_i R_{i,t} D(a)_i + \sum \gamma_i R(ABS)_{i,t} D(a)_i + \sum \beta_i R_{i,t} D(n)_i + \sum \gamma_i R(ABS)_{i,t} D(n)_i + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$R_{i,t}$ is logarithmic change in the spot price movement of the exchange rate i on day t, equal to ln (Pt/Pt-1), where P_t denotes the closing value of the exchange rate i on day t, while P_{t-1} denotes the closing value of the exchange rate i on day $t-1$;

$R(ABS)_{i,t}$ is absolute value of the daily rate of return $R_{i,t}$ of the exchange rate i on day t;

D(a) is the dummy variable for the announcements days, while D(n) is the dummy variable for the non-announcements days; and

ε_{it} is the error term

The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 8-5. Predictive Power of Implied Volatilities

1994-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0000	-0.01	-0.0005	-0.34	0.0006	0.451	-0.0015	-1.52
V (lag)	-0.0233	-1.17	-0.2434	-12.50***	-0.2598	-13.50***	-0.0502	-2.51**
R(F)	-0.0002	-0.18	-0.0011	-0.41	0.0019	0.99	0.0003	0.23

1994-1998

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	0.0003	0.24	-0.0006	-0.22	-0.0005	-0.20	-0.0017	-1.13
V (lag)	-0.0142	-0.49	-0.2776	-9.73***	-0.2829	-10.4***	-0.0019	-0.06
R(F)	0.0003	0.15	0.0022	0.38	0.0030	0.90	0.0015	0.80

1999-2003

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	Bi	t-stats	βi	t-stats
Constant	-0.0003	-0.29	-0.0003	-0.25	0.0015	1.00	-0.0013	-1.01
V (lag)	-0.0348	-1.26	-0.0360	-1.29	-0.2085	-7.42***	-0.1060	-3.83***
R(F)	-0.0006	-0.39	-0.0051	-2.5***	0.0009	0.41	-0.0015	-0.75

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

V(LAG): relation between contemporaneous and lagged volatility changes
R(F): the relation between daily implied volatility changes and the forward looking FX returns

The estimation is based on the following model:

$$\mathbf{V}_{i,t} = \alpha_0 + \sum \alpha_i \mathbf{V}_{i,t-1} + \sum \beta_i \mathbf{R(F)}_{i,t} + \varepsilon_{it}$$

where:

$V_{i,t}$ is logarithmic change in the implied volatility of the exchange rate i on day t, equal to ln (IVt/IVt-1), where IV_t denotes the daily implied volatility of the exchange rate i on day t, while IV_{t-1} denotes the daily implied volatility of the exchange rate i on day $t-1$;

$R(F)_{i,t}$ is logarithmic change in the price movement of the exchange rate i on day $t+1$, equal to ln (Pt+1/Pt), where P_t denotes the closing value of the exchange rate i on day t, while P_{t+1} denotes the closing value of the exchange rate i on day $t+1$; and

ε_{it} is the error term

The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

Table 8-6. Predictive Power of Extreme Implied Volatilities (1994-2003)

	USD/EUR		USD/GBP		USD/CHF		USD/JPY	
	βi	t-stats	βi	t-stats	βi	t-stats	βi	t-stats
				Extreme Implied Volatility				
HIV-PR	0.0032	1.41	0.0356	0.95	-0.0094	-0.81	0.0000	-0.03
HIV-NR	-0.0121	-1.59	-0.0577	-1.29	0.0014	0.24	0.0163	3.51***
LIV-PR	0.0012	0.84	0.0101	0.43	-0.0094	-0.92	0.0002	-0.32
LIV-NR	-0.0034	-1.21	-0.0354	-0.37	0.0025	0.33	0.0002	-0.05

*significant at 10% significance level
**significant at 5% significance level
***significant at 1% significance level

HIV-PR: impact of high implied volatility on positive returns
HIV-NR: impact of high implied volatility on negative returns
LIV-PR: impact of low implied volatility on positive returns
LIV-PR: impact of low implied volatility on negative returns

The estimation is based on the following model:

$$V_{i,t,pos(neg)} = \alpha_0 + \sum \alpha_i V_{i,t-1} + \sum \beta_i R^2(F)_{i,t,pos(neg)} + \varepsilon_{it}$$

where:
$V_{i,t,pos(neg)}$ is positive (negative) logarithmic change in the implied volatility of the exchange rate i on day t higher than one standard deviation above (below) its ten year mean
$R^2(F)_{i,t,pos(neg)}$ is squared positive (negative) logarithmic change in the price movement of the exchange rate i on day $t+1$.
ε_{it} is the error term

The lagged values of the $V_{i,t}$ are included to control for the volatility persistency.

CHAPTER 9. CONCLUSION

The purpose of this study is to examine an impact of news announcements on the FX implied volatility, identify seasonality patterns and anomalies in the FX returns and implied volatilities, and finally to study return – implied volatility relation in the FX market. The analysis is based on daily return and implied volatility data for four major exchange rates for a sample period of January 1994 to December 2003. By splitting a sample period into two five-year periods, preceding and following the euro introduction in 1999, we have a unique opportunity to study the impact of the euro introduction on the FX announcement effect, seasonality patterns and return – volatility relation.

Although many of our findings agree with the existing literature on the equity patterns and seasonalities (eg announcement effect as documented by Nikkinen and Sahlstrom, 2004), some contradict the findings of the prior studies on the equity markets (eg return –implied volatility relation as documented by Litvinova, 2002, Giot, 2003 and Bollerslev et. al, 2006). Most of our results agree with the findings on the FX futures (Kim and Kim, 2004). As one of our main contributions to the existing literature, we observe significant changes in many patterns/seasonalities/relations following the introduction of euro that we try to explain by the increased uncertainty, indicated by higher standard deviation of the implied volatility.

In this chapter, we summarize our results, which suggest that there is a number of patterns and seasonalities that could be observed in the FX cash market. Although, we do not try to conclude whether it would be possible to generate abnormal returns using a trading strategy based on these patterns, this could be a focus of future studies[1]. Although Harvey and Whaley (1992), Ederington and Lee (1996) and Kim and Kim (2004) showed that it would be difficult to obtain abnormal

[1] For example, one could argue that given a positive relation between implied volatility and option price, it could be possible to make profit by creating a delta neutral portfolio and issuing an option prior to the expected fall in the implied volatility (eg on Wednesdays or prior to the news announcements), when the option price is high and buying it back when the implied volatility is expected to rise (eg Mondays or following the announcements).

trading profits (after adjusting for the transaction costs) based on the observed patters in the equity, interest rate and FX futures markets, respectively, their findings show that abnormal returns could be generated when the underlying price volatility is relatively low. Other potential areas of study include the use of a higher frequency (intraday) and more recent data, inclusion of more variables (eg denoting volumes, order flow and etc.) into the model, the extension of the announcement effect studies to non US and conflicting macro announcements and the study of the implied volatility behavior on each of the five days prior to and following the announcements.

We provide a brief summary of the announcement effect in the FX implied volatilities in section 9.1. In sections 9.2 and 9.3, we summarize our findings on the seasonality patterns in the FX returns and implied volatilities, respectively. Section 9.4 provides a brief summary of the relation between FX returns and implied volatilities. Finally, section 9.5 summarizes shortcomings of our study and areas for future work, while section 9.6 concludes.

9.1. Announcement Effect in the FX Implied Volatilities – Conclusion

Chapter 5 discusses the impact of the announcements of sixteen major US macro indicators, FOMC minutes, official US interest rates and the impact of BoJ interventions on the implied volatility of four major exchange rates. We discuss the results in section 9.1.1 and highlight our contributions in section 9.1.2.

9.1.1. Announcement Effect in the FX Implied Volatilities - Results

The results indicate that the currency market implied volatility tends to increase prior to macro announcements and tends to fall on the announcements day. The impact of the macro announcements on the volatility during 5 days following the announcement day is muted. The results confirm the findings by Nikkinen and Sahlstrom (2004) for the stock market and findings by Degennaro and Shrieves (1997), Kim et. al (2004) and Bauwens (2005) for the FX market. We try to explain such behavior of the FX volatility by the private information theory[2] and lack of the "surprise" news.

We find an evidence of an increase in the FX implied volatilities prior to the BOJ interventions, but conclude that unlike macro announcements, interventions are not followed by the fall in the volatility. Consistent with Frenkel et. al (2004) and Bauwens et. al (2005), we report a significant increase in the implied volatility of all four exchange rates on the BOJ intervention day. Such phenomenon could be explained by the unawareness of the market participants about the event and the flow of new unexpected information into the market. The results also suggest that the significant impact of the BOJ interventions on the FX volatility is caused by the magnitude of the interventions and by Yen sales, but not purchases.

We conclude that the impact of macro announcements' surprise element on the FX volatility is not significant for most indicators, implying that the mere release

[2] According to the private information theory of Admati and Pfeiderer (1988) and Foster and Viswanathan (1990), informed traders prefer to trade during period of high trading activity to maximize potential profit that comes from the private information.

of the macro indicators, rather than the surprise news, affects currency market volatility[3]. We agree with Andersen et. al (2003), Chan et. al (2003) and Laakkonen (2004) by providing an evidence of the sign effect, indicated by the stronger impact of bad news on the market volatility compared to the good news. We conclude that FX implied volatility is affected by both large and small surprises.

9.1.2. Announcement Effect in the FX Implied Volatilities - Contributions

As the contribution to the existing literature, we find that compared to DM, the Euro has become more sensitive to the macro announcements on the announcement days. We try to explain this phenomenon by an increased uncertainty caused by the introduction of euro (Heaney and Swieringa, 2003). Another contribution is that we find evidence of a changing announcement effect over time[4]. We study the impact of the BOJ interventions on the FX implied volatility and contribute to the existing literature by suggesting that not only the mere presence of the BOJ at the market, but also the magnitude of the interventions affects currency implied volatility.

We show that bad news have stronger impact on the FX implied volatility than good news (phenomenon known as a sign effect) and contribute to the existing literature by providing evidence of a weakening sign effect over time. Relatively significant impact of positive rather than negative news for few macroeconomic indicators, including GDP, can be explained by the sample period covered by the study (1998 – 2003), which is characterized by the economic recession in USA and therefore unfavorable expectations about the macro announcements. Another contribution of this study to the existing literature is that we also examine the asymmetric feature of the announcement effect in terms of the size of the surprise element. We find that for six announcements, large surprises tend to have more

[3] However, it is necessary to mention that had higher frequency data instead of daily data been used, more significant results could be obtained.

[4] For example, although Madura and Tucker (1992), Andersen and Bollerslev (1998) and Kim and Kim (2004) report significant impact of the trade balance announcements on the FX implied volatility in the period preceding euro, we find no evidence of a significant impact of the trade balance releases on the FX implied volatility for the period of 1998 – 2003.

significant impact on the FX implied volatility, while for five announcements implied volatility is affected more by the smaller surprises. We explain more significant impact of the large surprises by the expectations of the interest rate cuts, and smaller surprises by the fact that market participants are reluctant to trade after large surprises, and prefer to trade after the news releases with smaller unexpected component.

9.2. Seasonality Patterns in the FX Return Series – Conclusion

The purpose of Chapter 6 is to study calendar anomalies in the FX return series. The seasonality patterns studied in this study are the day of the week effect, month of the year and intra-monthly patterns, the turn of the year and the holiday effect. The results are discussed in section 9.2.1, while section 9.2.2 provides a summary of our contributions to the existing literature.

9.2.1. Seasonality Patterns in the FX Return Series - Results

We find evidence of the day of the week effect in the FX return series, confirming the findings of Aydogan and Booth (1999) and Yamori and Kurihara (2004) for the currency markets. We report negative Friday returns and positive and significant Thursday returns. After finding evidence of a significant relation between FX return series and US macroeconomic announcements, we explain positive and significant Thursday and negative Friday returns by the invoicing patterns in the world trade and the response of speculator and dealers to the major scheduled news announcements. We also try to explain negative and significant Friday returns by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990). We do not find any significant evidence of the Monday effect documented for the equity markets (French, 1980, Jaffe and Westerfield, 1985 and Ball and Bowers, 1986) and explained by the private information hypothesis. We conclude that since FX is a 24 hour market, there is less opportunity in the currency market for informed traders to take advantage of uninformed traders, which explains why we do not see a Monday effect. We do not find a significant evidence of more pronounced intraweek patterns in 1999-2003 period.

We find an evidence of the January effect. We offer several explanations for the negative and statistically significant January returns, which includes the actions of speculators and dealers prior to the holidays, money managers' inclination to make long-term reassessments of FX trends at the end and beginning of the calendar year, and the tax loss-selling hypothesis, which explains January effect in the US stock market (Roll, 1983 and Tinic and Barone-Adesi, 1983). We find an evidence of the negative and statistically significant November returns, which is consistent with the hypothesis that the tax loss selling explains monthly seasonality patterns. Although Bhabra et. al (1999) reports November effect in the US stock market after 1986, when the Tax Reform Act of 1986 changed the tax year-end for all mutual funds to realize capital gains and losses to October 31st from December 31st, we link November effect in the FX market to the tax loss selling. By recognizing that the tax and calendar years coincide, which implies that most tests are the joint tests of two year-ends (Hillier and Marshall, 2002), we test tax loss selling hypothesis by hypothesizing that if the tax loss selling explains monthly seasonality patterns, we should observe April effect for USD/GBP, since in the UK, the tax year-end for investors is April 5. We do find some evidence in support of the tax loss-selling hypothesis, but the results suggest that the tax loss selling is not the only factor that explains monthly patterns observed in the currency markets. We explain positive and statistically significant September returns by the September effect in the US stock market, leading to USD depreciation, consistent with the portfolio adjustment / capital movement theory. We conclude that although there is evidence of the month of a year effect in the FX markets, the effect is not persistent, and has not been significantly affected by the introduction of euro.

We do not find any evidence of the average daily currency returns in the first half of a month being significantly different from the average daily return in the second half of a month. Although, we find evidence of the average daily return being positive in the first three days and negative in the last three days of a month, none of the regression coefficients is significant[5]. This implies that in the currency markets, there is either no turn of the month effect, or as suggested by Ziemba (1989) for Japanese stock market, the turn of the month effect occurs over a different sequence of days. The results contradict the findings of the researchers who found evidence of the turn of the month effect in the international equity (Ariel, 1987, Agrawal and Tandon, 1994, and Boudreaux, 1995) and to some extent in the FX markets (Liano and Kelly, 1995 and Aydogan and Booth, 1999). We explain our

[5] The coefficients reported for the first three days of a month are statistically significant for the period of 1999-2003 for USD/EUR

findings by the fading feature of the turn of the month effect (Agrawal and Tandon, 1994), and the fact that the currency markets are more efficient compared to the stock market, and therefore display weaker calendar patterns.

We find evidence of a turn of the year effect in the FX market, confirming the findings of Ariel (1987), Lakonishok and Schmidt (1988) and Howe and Wood (1993) reorted for the equity markets. We find that the average daily return in the last three business days in December is positive and statistically significant, while the average daily return in the first three business days in January is negative, but statistically less significant. We explain these results by the fact that the portfolio managers sell loss-making stocks to realize capital gains and losses in the last three days in December, resulting in USD depreciation. Less significant January coefficients could be explained by the fact that it takes longer than three days for USD to return to the previous level.

Finally, we study the holiday effect, and find evidence of the positive pre holiday and negative post holiday average return. Although we confirm the findings of the studies on the pre holiday effect (Aydogan and Booth, 1998 for the FX and Howe and Wodd, 1993 and Wood, 1994 for the stock markets), only for USD/EUR we obtained statistically significant results. This is as evidence of a weakening pre holiday effect, which has already been documented in the equity (Tan and Tat, 1998) and currency markets (Liano, 1995). We explain the holiday effect mainly by the tendency of the banks to flatten their natural long USD positions prior to the official holidays.

Throughout our study, we test the robustness of the results to address concerns levied by Connolly (1989), Lindley and Liano (1997), Sullivan et. al (1998) and others regarding the robustness of anomaly research. We obtain similar results, regardless of whether Monday or Tuesday dummy variables are excluded to avoid the dummy variable trap. For the turn of the year effect, we generate similar results, regardless of whether we define turn of the year as the first or the last, 3 or 10 working days of the year. Finally, for the turn of the month effect, defining turn of the month as the last three, first three or six days around the end of the month, generate similar results. These tests confirm that the study result are robust to the choice of the regression model.

9.2.2. Seasonality Patterns in the FX Return Series - Contributions

Although, there is some, though limited literature on the FX day of the week effect (Hilliard and Tucker, 1992, Cornet et. al, 1995 and and Aydogan and Booth, 1999), the literature on other seasonality patterns in the FX return series is very limited, providing an opportunity to contribute to the existing literature by studying whether the documented anomalies are unique to the stock market.

When studying the day of the week effect in the FX returns, we find evidence of not only negative Friday returns, which has already been documented for the FX (Cornet et. al, 1995) and equity (Jaffe and Westerfield, 1985 and Ball and Bowers, 1986) markets, but also report positive and significant Thursday returns, which is a contribution to the existing literature on the FX intraweek patterns. After finding an evidence of a significant relation between FX return series and US macroeconomic announcements, we explain positive and significant Thursday returns by the invoicing patterns in the world trade and the response of speculator and dealers to the major scheduled news announcements.

We contribute to the existing literature on the monthly seasonalities, by finding that the January effect documented for the equity and bond markets (Schultz, 1985 and Jones et. al, 1987) also exists in the currency markets. We further contribute to the existing literature by confirming that the January effect tends to strengthen in the "bad" years characterized by low GDP growth rate, and tends to weaken in the "good" years characterized by high GDP growth rate. We find evidence of the negative and statistically significant November returns, and contribute to the existing literature by linking November effect in the FX market to the tax loss selling. Finally, we find evidence of stronger monthly anomalies in 1994-1998 period compared to 1999-2003, and explain this by the fact that the markets have adjusted for the calendar anomalies as the monthly seasonalities became well-known phenomenon and the tax shelters removed any reason for selling in order to create a tax loss.

We find evidence of a turn of the year effect in the FX market. Our contribution is that we find evidence in support of the hypothesis that the effect has become more pronounced in post euro period, and explain this by the increased currency market volatility and higher sensitivity of the exchange rates to the calendar anomalies in post euro period, characterized by USD depreciation.

We do not find any evidence in support of the theory proposed by Lakonishok and Schmidt (1988), according to which, the behavior of the equity prices prior to holidays should be similar to that on Fridays (just before a weekend) and the behavior of the prices after holidays should be similar to that on Mondays[6]. Contributing to the existing literature, we explain the results by the fundamental difference between stock and FX market structures and by the fact that there is less opportunity in the FX market for informed trader to take advantage of uninformed traders. We consider this as evidence supporting the hypothesis that the calendar seasonalities in the FX market are different from those in the equity market due to the different market structures. We find that the holiday effect tends to weaken after 1999, and explain this by the increased interdependence among geographic markets, which reduces a need to flatten positions prior to holidays. Finally, we study the impact of non-US holidays on the FX market, and contribute to the existing literature on the FX holiday effect, by concluding that the FX holiday effect is mainly driven by the US rather than European, Japanese and UK holidays.

[6] the theory is explain by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990).

9.3. Seasonality Patterns in the FX Implied Volatilities – Conclusion

Chapter 7 focuses on the seasonality patterns in the FX implied volatilities. The seasonality patterns studied in this thesis are the day of the week effect, the turn of the year and the turn of the month effects, monthly and quarterly patterns and finally the holiday effect. The results are discussed in section 9.3.1, while section 9.3.2 provides a summary of our contributions to the existing literature.

9.3.1. Seasonality Patterns in the FX Implied Volatilities – Results

We find a strong evidence of the day of the week effect in the FX implied volatilities, which has already been documented for the equity and currency futures volatilities by Harvey and Huang (1991) and Ederington and Lee (1996). The day of the week effect is indicated by the positive implied volatility changes on Monday and Tuesday and negative implied volatility changes on Thursday and Friday. The Monday regression coefficients are statistically significant for all exchange rates, while the coefficients for the remaining days are statistically significant for at least two exchange rates. We explained high Monday and Tuesday volatilities mainly by the private information hypothesis of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), and relatively low Thursday and Friday volatilities by the announcements effect. Consistent with Muller et. al (1990), we conclude that volatility is low on weekends compared to the trading days and tend to be higher on Sunday than on Saturday, due to some trading activity in some Middle Eastern markets, which are open on Sunday and early Monday morning activity in East Asian markets, which coincide with Sunday nights in GMT.

We also find an evidence of the strong turn of the year effect in the FX implied volatilities. The results suggest that the implied volatility tend to increase during the last 30 and the first 2 days of the year, before declining between trading +2 and +10. This behavior of the implied volatility around the turn of the year has already been documented at the equity markets by Rogalski and Tinic (1986) and Rogalski and Maloney (1989) and could be explained by Rogalski and Maloney's

(1989) seasonal risk premium hypothesis and the concentrated liquidity-trading hypothesis by Lakonishok and Smidt (1986).

We do not find a strong evidence of the monthly or quarterly patterns in the FX implied volatilities, noting that the quarterly patterns become more significant in the second sample period of 1999-2003, which could be due to the USD depreciation and the fact that seasonality patterns are more obvious in the declining markets. We find that the FX implied volatility is positive and statistically significant for USD/CHF around the turn of the month, even after excluding the year ends, implying that there is some, though not very significant evidence of the turn of the month effect in the FX implied volatilities. Increased volatility around the turn of the month is explained by the substantial payments to private investors in the US economy and the fact that most corporate and municipal debt in the USA is payable on the first and last days of the month, affecting USD volatility.

Finally, we report decreased implied volatility prior to and increased implied volatility following holidays, confirming the fact that the holiday effect documented by Tanizaki (2004) for the Japanese equity index exists in the FX market. By hypothesizing that the market activity during and around the holidays resembles the behavior of the volatility prior to and around the weekends, we try to explain decreased implied volatility prior to the holidays by traders' trading patterns and the increased selling pressure due to many traders closing their positions before the holidays. Consistent with Foster and Viswanathan (1990), we explain positive and statistically significant implied volatility change following the holidays by the traders using private information accumulated during the holidays before the information is publicly disseminated.

9.3.2. Seasonality Patterns in the FX Implied Volatilities – Contributions

Although, there is some, though limited literature on the intraweek currency volatility patterns, the literature on other seasonality patterns in the FX implied volatilities is very limited, providing an opportunity to conduct an innovative piece of research. Our most significant contribution to the existing literature on the day of the week effect in the implied volatilities is that the day of the week effect has become more obvious following the introduction of the euro. We try to explain this phenomena by the euro being more volatile currency than the DM (Heaney and Swieringa, 2003), the concentration of euro related announcements on Thursday and Friday, the strengthened impact of the private information based trading on the implied volatility (McGroarty et. al, 2005), and finally by the USD depreciation and the theory that seasonality patterns become more obvious in a declining rather than rising markets (Chang et. al, 1993, Fishe et. al, 1993 and Arsad and Coutts, 1997 and Steeley, 2001).

We find an evidence of the strong turn of the year effect in the FX implied volatilities and show that similar to the equity markets (Rogalski and Tinic, 1986 and Rogalski and Maloney, 1989), the FX implied volatility tends to increase prior to the year-end before declining two days after the year-end. Although a fall in the equity implied volatility starts two days prior to the year end (documented by Rogalski and Maloney, 1989), we found FX implied volatility starting to decline only after two days following the turn of the year. This is one of our contributions and could be explained by the fact that the seasonality patterns in the currency implied volatilities, including the turn of the year effect, are relatively longer lived compared to those in other markets' volatilities. We note that the turn of the year effect is more significant in the sample period preceding the introduction of euro and explain a declining trend in the turn of the year effect over time by the diminishing January effect in the financial markets.

9.4. Relation Between FX Returns and Implied Volatilities – Conclusion

Chapter 8 focuses on the relation between FX returns and implied volatilities, by covering three main areas: (a) the contemporaneous relation between FX returns and implied volatilities, (b) the asymmetric feature of this relation and finally (c) the ability of the FX implied volatility to predict future returns. Section 9.4.1 provides an overview of the results, while section 9.3.2 focuses on the contributions of the chapter 8 to the existing literature.

9.4.1. Relation Between FX Returns and Implied Volatilities – Results

There is an evidence of a strong relation between implied volatility and contemporaneous returns, which is significantly positive for USD/EUR, USD/CHF and USD/JPY, and significantly negative for USD/GBP. This result contradicts the outcome of the studies on the relation between stock market contemporaneous returns and volatilities (Litvinova, 2002, Giot, 2003 and Bollerslev et. al, 2006), which suggested that the volatility – return relation is negative, but is consistent with the findings of the studies on the currency futures (Davidson et. al, 2001 and Kim and Kim, 2004). Both large appreciation and large depreciation of USD against foreign currencies was found to cause a significant increase in the currency market uncertainty, denoted by the implied volatility.

In the second part of the thesis, the attempt is made to address the asymmetric feature of the volatility – return relation in terms of the size and direction of the exchange rate movements. Besides, the impact of the contemporaneous FX returns on the implied volatility is studied on both the announcement and non-announcement days. Contrary to the existing literature on the stock market (Engle and Ng, 1993, Fleming et. al, 1995 and Dumas et. al, 1998), but consistent with the findings on the currency market (Malz, 2000, Davidson et. al, 2001 and Kim and Kim, 2004), no evidence of the asymmetric impact of the implied volatility on the FX returns is found. In addition, the results indicate that both positive and negative FX returns are associated with the increased implied volatility, the conclusion that contradicts the existing findings on the equity market (Fleming et. al, 1995 and Davidson et. al, 2001) and on the bond market (Simon, 1997), but is consistent with the results reported for the currency futures (Davidson et. al, 2001 and Kim and Kim, 2004). The impact of small returns on the FX implied volatility is found to be stronger than the impact of large returns, albeit the evidence is not significant enough to suggest that the relation is significantly asymmetric. There is also some evidence that the implied volatility – return relation in the FX market is affected by the news announcements.

Although no strong evidence of the relation between currency market implied volatilities and the forward looking returns is found, the relation becomes more significant, when only extreme levels of the implied volatility are considered. Although, only one coefficient is significant at 1% significance level, the results confirm the findings by Malz (2000) and Giot (2003).

9.4.2. Relation Between FX Returns and Implied Volatilities – Contributions

We find an evidence of a strong relation between implied volatility and contemporaneous returns and contribute to the existing literature by showing that the relation has declined in significance following the introduction of euro. This could be explained by the fact that the introduction of euro resulted in the increased expected uncertainty, indicated by higher standard deviation of the implied volatility in post euro sample period, but do not cause significant movements in the exchange rates, as indicated by the unchanged standard deviation of the returns.

After finding that small FX returns affect implied volatility slightly stronger than large returns, we show that this phenomenon is more obvious in 1999 – 2003 period. We explain this by the behavior of the option traders, who tend to react aggressively to the movements in the exchange rates, when normal market conditions prevail, by strongly bidding up implied volatility, but are reluctant to do so in the uncertain market conditions, associated with the extreme movements in the exchange rates and higher volatility of volatility. This leads to another contribution to the existing literature: the asymmetric impact of small and large returns on the FX implied volatility is more significant in the high volatility environment following the introduction of euro.

As another contribution, we examine whether the relation between contemporaneous returns and implied volatilities is affected by the news announcements. The results indicate that the relation between the magnitude of the returns and implied volatilities is statistically more significant on non-announcement days. We find that both the appreciation and depreciation of USD against foreign currencies on non-announcement days is associated with the significant rise in the implied volatility, with no significant results reported for the announcement days. A big move in the FX rate on non-announcement days result in the increased uncertainty as traders expect further large moves and therefore higher implied volatility. However, on the announcement days, the expected rise in the volatility resulting from the USD depreciation tend to be offset by the fall in the implied volatility caused by the release of the important news announcements, as traders link large moves in the FX rates to the news release. These findings confirm that the macroeconomic news announcements have a significant impact on the implied volatility patterns[7], including FX implied volatility – return relation, and is one of the main contributions of this study to the existing literature.

Although no strong evidence of the relation between currency market implied volatilities and the forward looking returns is found, there is a consistency among the exchange rates in terms of the sign of the regression coefficients in pre and post euro periods. The sign of the coefficient suggests that the increase in the FX market volatility is associated with the depreciation of US Dollar in pre-euro period, but with the appreciation of USD in the period following the introduction of euro. We also find an evidence of the significance impact of the extreme levels of the implied volatility on the forward looking returns and contribute to the existing literature by showing that this impact is found to be particularly significant for negative (as

[7] Ederington and Lee (1996) explain a day of the week effect in the FX implied volatility by the release of the US scheduled announcements

opposed to positive) returns and for extremely large increases (as opposed to decreases) in the level of the implied volatility.

9.5. Limitations and Areas for Future Study

Although, we do not try to conclude whether it would be possible to generate abnormal returns using a trading strategy based on the patterns and relations identified in our thesis, this could be a focus of future studies. For example, one could argue that given a positive relation between implied volatility and option price, it could be possible to make profit by issuing an option prior to the expected fall in the implied volatility (eg on Wednesdays or prior to the news announcements of the unemployment data, GDP or CPI), when the option price is high and buying it back when the implied volatility is expected to rise[8] (eg Mondays or following the announcements). Alternatively, one could buy an option prior to the expected rise in the implied volatility and sell it when the volatility is expected to fall. Although Harvey and Whaley (1992), Ederington and Lee (1996) and Kim and Kim (2004) showed that it would be difficult to obtain abnormal trading profits (after adjusting for the transaction costs) based on the observed patters in the equity, interest rate and FX futures markets, respectively, their findings show that abnormal returns could be generated when the underlying price volatility is relatively low. Therefore, the first area of future study could be the construction of the delta-neutral trading portfolio based on the patterns identified by us to see whether these trading strategies generate profits in excess of the transaction costs.

Some limitations of this study are worth discussing, as they could indicate the areas of future studies. The choice of the sample period could influence the results, as patterns tend to appear in some periods and disappear in others. Based on the conversations we had with practitioners (FX option traders), we understand that although few years ago, FX implied volatilities have been affected more by the announcements during the working week, in the current environment, which could be considered a significant outlier, speeches by the government officials and weekends (which tend to coincide with G8 or G20 meetings or bank collapses, eg Lehman Brothers) are becoming more important. We do recognize that the use of a more recent data would be required to predict patterns in the current environment, but note

[8] A delta neutral position (eg a combination of a put and a call) could be created to hedge against a loss due to unfavourable changes in the underlying FX rates

that we do anticipate the normal patterns (that we observed using our data sample) to emerge once the markets stabilize again.

Although the use of daily volatility series allows to cover ten years period, it may undermine an accuracy of the results. For example, when studying the announcement effect, in order to achieve more accurate results and to capture an immediate impact of the news announcements on the market volatility, higher frequency data should be used. Litvinova (2003) and Bollerslev et. al (2006) suggested that the inability of previous studies to reach a consensus in determining the main components of volatility – return relation and volatility asymmetry may be due to the loss of information in low frequency data (daily, weekly or even monthly) and the different features of leverage and volatility feedback effects in low and high frequency data. However, we note issues connected with the use, analysis, and application of high frequency data sets, such as the effects of market structure on the availability and interpretation of the data, methodological issues such as the treatment of time, the effects of intra-day seasonals, and the effects of time-varying volatility, and the information content of various market data (Goodhart and O'Hara, 1997). Nevertheless, the study of the FX volatility patterns and return – implied volatility relation using higher frequency (intraday) data represents another potential area of study.

Another limitation is that additional factors impact FX volatility, the ignorance of which may cause biased estimates. For example, Bollerslev and Domowitz (1993), Melvin and Yin (2000), Andersen et. al (2002) and Evans and Lyons (2004) have documented a strong relationship between market activity, measured by the order flow and FX volatility. Therefore, to achieve more accurate results, several factors should be considered in the analysis. In order to address this issue, we tried to incorporate the impact of several factors (anomalies) in the same regression model. For example, when examining the day of the week effect and return - implied volatility relation, we considered the announcement effect and when studying holiday effect and monthly patterns, we included additional variables to control for the turn of the year effect. However, the accuracy of the results could improve further if more variables (eg denoting volumes, order flow and etc.) could be incorporated into the model, representing yet another area for future research.

There are few limitations relating to the study on the announcement effect. The announcements and most importantly, the proxy used to measure the expectation of the announcements (consensus estimates provided by the finance service of the www.yahoo.com) may be noisy indicators of actual macro surprises (Dominguez and Panthaki, 2005). The use of the sixteen US scheduled macro announcements implies that the results are subject to the assumption that the sixteen indicators capture all the announcement effect. Another potential weakness is that sometimes it is difficult to infer whether news are positive or negative. For example, although higher than expected CPI and PPI releases indicate inflation, which is unfavorable news, lower than expected CPI and PPI figures in the economy characterized by the recession are also unfavorable[9]. In addition, it is common for several macro indicators to be announced at the same time. If some of them are positive and some of them are negative, this gives conflicting indications on future developments for the investors, and makes it difficult to classify individual news as either bad or good. Although, this topic is outside a scope of this study, Laakkonen (2004) found conflicting news to have stronger impact on the volatility of USD/EUR than consistent news. Besides, it would be worthwhile to see how implied volatility behaves not only during five days prior to and following the announcements, but also during each of these fives days around the announcements. All these limitations could represent key points for further research on the impact of news announcements on the currency market volatility, such as: (i) the impact of non US news announcements on the FX implied volatility, (ii) impact of the conflicting macro news announcements on the FX implied volatility, (iii) impact of news announcements on the FX implied volatility one and three days prior to and following the announcements.

[9] declining inflation is the sign of the further slowdown in the economy

9.6. Summary

We examine an impact of news announcements on the FX implied volatility, try to identify seasonality patterns and anomalies in the FX returns and implied volatilities, and finally study return – implied volatility relation in the FX market. The analysis is based on daily return and implied volatility data for four major exchange rates for a sample period of January 1994 to December 2003. By splitting a sample period into two five-year periods, preceding and following the euro introduction in 1999, we contribute to the existing literature by studying the impact of the euro introduction.

Although many of our findings agree with the existing literature on the equity patterns and seasonalities (eg announcement effect as documented by Nikkinen and Sahlstrom, 2004), some contradict the findings of the prior studies on the equity markets (eg return –implied volatility relation as documented by Litvinova, 2002, Giot, 2003 and Bollerslev et. al, 2006). Most of our results agree with the findings on the FX futures (Kim and Kim, 2004). As one of our main contributions to the existing literature, we observe significant changes in many patterns/seasonalities/relations following the introduction of euro that we try to explain by the increased uncertainty, indicated by higher standard deviation of the implied volatility.

The natural question would be whether it is possible to generate abnormal returns using a trading strategy based on the patterns – the question that could represent a focus of future studies. Other potential areas of study include the use of a higher frequency (intraday) and more recent data, inclusion of more variables (eg denoting volumes, order flow and etc.) into the model, the extension of the announcement effect studies to non US and conflicting macro announcements and the study of the implied volatility behavior on each of the five days prior to and following the announcements.

CHAPTER 10. REFERENCES

Abraham, A. and Ikenberry, D. (1994), The individual investor and the weekend effect. Journal of Financial and Quantitative Analysis 29, 263-278.

Admati, A., and Pfleiderer, P. (1988), A theory of intraday patterns: Volume and price variability. Review of Financial Studies, 1, 3–40.

Aggarwal, R. and Rivoli, P. (1989), On the relationship between the United States' and four Asian equity markets, Asean Economic Bulletin, 6, 110- 117.

Aggarwal, R. and Rivoli, P. (1989), Seasonal and day-of-the-week effects in four emerging stock markets. Financial Rev. 24, 541–550.

Aggarwal R. and Schirm (1998), Asymmetric impact of trade balance news on asset prices, Journal of International Financial Markets, Institutions and Money 8, 83-100.

Aggarwal, A., and Tandon, K. (1994), Anomalies or illusions? Evidence from stock markets in eighteen foreign countries, Journal of International Money and Finance 13, 83-106.

Alexakis, P. and Xanthakis M. (1995), Day- of- the- Week Effect on the Greek stock market, Applied Financial Economics, 5, 43- 50.

Almeida, A., Goodhart, C. and Payne, R. (1998), The Effects of macroeconomic news on high frequency exchange rate behavior, The Journal of Financial and Quantitative Analysis, 33, 383–408.

Alper, C. and Arouba, S. (2001), Deseasonalizing macroeconomic date: a caveat to applied researchers in Turkey. ISE Review, 5 (18), 33-52.

Amihud, Y. and Mendelson, H. (1987), Trading mechanisms and stock returns: an empirical investigation, Journal of Finance, 42, 533-553.

Andersen, T. and Bollerslev, T. (1998), Deutsche mark–dollar volatility: Intraday activity patterns, macroeconomic announcements, and longer run dependencies, Journal of Finance, 53 (1), 219–265.

Torben A. G. and Bollerslev T. (1994), Intraday seasonality and volatility persistence in foreign exchange and equity markets, Department of Finance, Kellogg Graduate School of Management, Northwestern University.

Torben A. G., Bollerslev T., Diebold, W. F. and Labys, P. (1999), Understanding, optimizing, using and forecasting realized volatility and correlation, New York University, Leonard N. Stern School Finance Department, Working Paper Series.

Torben A. G., Bollerslev T., Diebold, W. F. and Vega, C. (2003), Micro Effects of Macro Announcements: Real Time Price Discovery in Foreign Exchange, Working Papers 02-16, Duke University, Department of Economics.

Andrews, D. W. (1991), Heteroskedasticity and autocorrelation consistent covariance matrix estimation, Econometrica, 59, 817--858.

Anthony, J. (1988), The Interrelation of Stock and Option Market Trading-Volume Data, Journal of Finance 43, 949-964.

Ariel, R. A. (1988). Evidence on intra-month seasonality in stock returns: In E. Dimson (ed.), Stock Market Anomalies, 109–119, Cambridge, Cambridge University Press.

Ariel, R. (1987), A Monthly Effect in Stock Returns. Journal of Financial Economics, 18, 161–174.

Ariel, R. (1990), High Cost Returns Before Holidays: Existence and Evidence on Possible Causes, The Journal of Finance, 45, 1611–1626.

Arsad, Z. and Coutts, J. A. (1996), The weekend effect good news bad news and the financial times industrial ordinary shares index: 1935–1994, Applied Economics Letters, 3, 797–801.

Arsad, Z. and Coutts, J. A. (1997), Security price anomalies in the London international stock exchange: a 60 year perspective. Applied Financial Economics, 7 (5), 455-464.

Athanassakos, G. and Robinson, M. J. (1994), The Day of the Week Anomaly: The Toronto Stock Exchange Experience, Journal of Business Finance and Accounting, 21, 833-56.

Arumugam, S. (1999), Focus on high stock returns before holidays: new evidence from India. Journal of Financial Management and Analysis, 12 (2), 69-84.

Aydogan, K. (1994), Hisse Senedi Fiyatlamasinda Aykiriliklar, Isletme ve Finans Dergisi, 83-89.

Aydogan, K. and Booth, G. (1999), Calendar Anomalies in the Turkish Foreign Exchange Markets, Journal of Applied Financial Economics, 13 (5), 353-360.

Baestens, J. E. and Willem, M. V. (1996), Money market headline news flashes, effective news and the DEM/USD swap rate: An intraday analysis in operational time. In Forecasting Financial Markets: New Advances for Exchange Rates, Interest Rates and Asset Management, London. Third International Conference sponsored by Chemical Bank and Imperial College.

Bailey, W. (1986), Economic News and Asset Price Uncertainty, PhD dissertation, University of California, Los Angeles.

Bailey, W. (1988), Money Supply Announcements and the Ex Ante Volatility of Asset Prices, Journal of Money, Credit ad Bunking, 20, 611-620.

Baillie, R., and Bollerslev, T. (1990), Intra-day and inter-market volatility in foreign exchange rates, Review of Economic Studies, 58, 565–585.

Baillie and DeGennaro (1990), Stock Returns and Volatility, Journal of Financial & Quantitative Analysis, 25 (2).

Baillie, R. T. and Osterberg, W. P. (1997), Central Bank intervention and risk in the forward market, Journal of International Economics, 43, 483-97.

Baillie R. T. and Bollerslev, T. (1989), The message in daily exchange rates: a conditional variance tale, Journal of Business and Economic Statistics, 7, 297 – 305.

Baker R. and Limmack, R. J. (1996), Firm Size, Monthly Seasonalities and Tax Loss Selling: Further Evidence from the UK, British Accounting Review 30, 221–248.

Balaban, E. (1995), Day of the Week Effects: New Evidence From an Emerging Stock Market, Applied Economics Letters 2, 139- 143.

Balaban, E. and Bulu, M. (1996), Is There a Semi- monthly Effect in the Turkish Stock Market?, The Central Bank of the Republic of Turkey Discussion Paper No. 9606. Bradley, J. 1978. Distribution Free Statistical Tests, Englewood cliffs, NJ: Prentice-Hall.

Balduzzi, P., Elton, E. and Green, T. (1999), Economic news and the yield curve: Evidence from the US treasury market. Working paper, New York University, New York, NY.

Balduzzi, P., Elton, E. and Green, T. (2001), Economic news and Bond prices: Evidence from the US treasury market, Journal of Financial and Quantitative Analysis.

Ball, R. and Bowers J. (1986), Daily Seasonals in Equity and Fixed-Interest Returns: Australievidence and Tests of Plausible Hypotheses, Unpublished Working Paper, Australian Graduate School of Management.

Banz, R. (1981), The relationship between return and market value of common stocks, Journal of Financial Economics 9, 3-18.

Barberis, N., Shleifer, A. and Vishny, R. (1998), A Model of Investor Sentiment, Journal of Financial Economics, 49, 307-343.

Bauwens, L., Walid B. O. and Giot P. (2005), News announcements, market activity and volatility in the euro/dollar FX market, Journal of International Money and Finance 24, 1108 – 1125.

Barone-Adesi, G. and Cyr, D. (1994), A Test of Calendar Seasonalities in Stock Market Risk Implied from Index Futures Options, International Review of Economics and Finance, 3 (3).

Bates, D. S. (1991), The Crash of '87: was it expected? The evidence from options markets, Journal of Finance, 46 (3), 1009–1044.

Beattie, N., and Fillion, J. (1999), An intraday analysis of the effectiveness of FX intervention. Bank of Canada Working Papers, 99-4.

Beckers, S. (1981), Standard Deviations Implied in Option Prices as Predictors of Future Stock Price Variability, Journal/ of Banking and Finance, 5, 363-381.

Beine, M., Benassy-Quere A. and Lecourt C. (2002), Central Bank Intervention and Foreign Exchange Rates: New Evidence from FIGARCH Estimations, Journal of International Money and Finance, 21, 115-144.

Beine, M., Laurent S., and Palm F. (2005), Central Bank Forex Interventions Assessed Using Realized Moments, Working Paper.

Beine, M., Lahaye, J., Laurent, S., Neely, C. and Palm F. (2006), Central Bank Intervention and exchange rate volatility, its continuous and Jump components, Research Division, Federal Researve Bank of St. Louis, Working Paper Series 2006 – 031A.

Bekaert, G. and Harvey, C. R. (1997), Emerging equity market volatility, Journal of Financial Economics, 43, 29-77.

Bekaert, G. and Wu, G. (2000), Asymmetric Volatility and Risk in Equity Markets, The Review of Financial Studies, 13, 1-42.

Bekaert, G., Harvey C.R. and Ng, A. (2003), Market integration and contagion, NBER Working paper series, Working Paper 9150.

Benassy-Quéré, A., Mojon, B. and Pisani-Ferry, J. (1997), The Euro Exchange Rate Stability, Centre D'Etudes Prospectives et D'Informations Internationales (CEPII), Working Paper No. 97-12.

Berkman, N.G. (1978), On the significance of weekly changes in M1. New England Economic Review, 5-22.

Berry, T. D. and Howe, K.M. (1994), Public information arrival, Journal of Finance, 49, 1331-1346.

Berument, H., and Kiymaz, H. (2003), The day of the week effect on stock market volatility and volume: International evidence, Review of Financial Economics, 12, 363-380

Berument, H., Coskun, M. N. and Sahin, A. (2007), Research in International Business and Finance 21 (2007), 87-97

Bessembinder, H. and Seguin, P. (1993), Price Volatility, Trading Volume, and Market Depth: Evidence from Futures Markets, Journal of Financial and Quantitative Analysis 28, 21-41.

Biais, B. (1993), Price information and equilibrium liquidity in fragmented and centralized markets, Journal of Finance, 48, 157-185.

Bildersee J. and Kahn N. (1987), A Preliminary Test of the Presence of Window Dressing. Journal of Accounting, Auditing and Finance, 2, 239–256.

Bildik, R. (1997), Hisse Senedi Piyasalarinda Aykiriliklar: IMKB'nda Gun Etkisi, Unpublished Working Paper at Finance Department of Istanbul University.

Bishop, G., (1998), The European Central Bank and the Prudential Regulation of the Financial System, International Journal of Finance and Economics, 3, 13- 20.

Bhabra Harjeet S., Upinder S. Dhillon, and Gabriel G. Ramirez (1999), A November Effect? Revisiting the Tax-Loss-Selling Hypothesis - Statistical Data Included Financial Management (Financial Management Association).

Bhattacharya, M. (1987), Price Changes of Related Securities: The Case of Call Options and Stocks, Journal of Financial and Quantitative Analysis, 22, 1-15.

Bhattacharya, U. and Weller, P. A. (1997), The advantage to hiding one's hand: speculation and Central Bank intervention in the FX market, Journal of Monetary Economics, 39, 251-277.

Black, F. (1976), Studies of Stock Price Volatility Changes, Proceedings of the 1976 Meetings of the American Statistical Association, Business and Economic Statistics.

Black, F. (1986), Noise, Journal of Finance 41, 529-543.

Black, F. and Scholes, M. (1973), The pricing of options and corporate liabilities, Journal of Political Economy, 285 81, 637–654.

Board, J., and Sutcliffe C. (1995), The relative volatility of the markets in equities and index futures, Journal of Business Finance and Accounting, 22 (2), 201-223.

Bollerslev, T. (1986), Generalized Autoregressive Conditional Heteroskedasticity, Journal of Econometrics, 31, 307-327.

Bollerslev, T. and Domowitz, I. (1993), Trading patterns and prices in the inter-bank FX market, Journal of Finance, 48, 1421-1443.

Bollerslev, T., Cai J., Song F. M. (2000), Intraday periodicity, long memory volatility, and macroeconomic announcement effects in the US Treasury bond market, Journal of Empirical Finance, 7, 37-55.

Bollerslev T., Litvinova, and Tauchen (2006), Leverage and Volatility Feedback Effects in High Frequency Data, Journal of Financial Econometrics, 4(3), 353-384.

Bonser-Neal, C. and Tanner, G. (1996), Central Bank intervention and the volatility of FX rates: evidence from the options market, Journal of International Money and Finance, 15, 853-78.

Boothe P. and Glassman D. (1987), The statistical distribution of exchange rates, empirical evidence and economic implications. Journal of International Economics, 22, 297–319.

Booth, G. and Chowdhury M. (1996), Information Noise and Stock Return Volatility: Evidence from Germany, Journal of Applied Economics Letters, 3(8), 537-40.

Boudreaux, D.O. (1995), The Monthly Effect in International Stock Markets: Evidence and Implications, Journal Of Financial And Strategic Decisions, 8(1).

Boyer, R.S. (1977), Devaluation and portfolio rebalance, American Economic Review, 67, 54-63.

Boyle P., Byoun, S., and Park, H. Y. (1999), Temporal Price Relation Between Stock and Options Markets and a Bias of Implied Volatility in Option Prices, OFOP Paper No. 99-07.

Brailsford, T. J. and Easton, S.E. (1993). New evidence on the impact of tax-loss selling on the turn of the year effect, Journal of Banking and Finance, 17, 131–144.

Branch, B. (1977), A tax loss trading rule, Journal of Business 50, 198-207.

Breen (1989), Economic Significance of Predictable Variations in Stock Index Returns, Journal of Finance, 44, 1177 – 1189.

Brock, W., and Kleidon, A. (1992), Periodic market closure and trading volume: A model of intraday bids and asks, Journal of Economic Dynamics and Control, 16, 451–489.

Brooks, C. and Henry, O.T. (2002), The impact of news on measures of undiversified risk, Oxford Bulletin of Economics and Statistics 64, 487 – 508.

Brown, P., Keim, D.B., Kleidon, A. W. and Marsh, T. A. (1983), Stock return seasonalities and the 'tax-loss selling' hypothesis: Analysis of the arguments and evidence, Journal of Financial Economics 12, 105-127.

Brown, K.C., Harlow, W.V., Tinic, S.M. (1988), Risk aversion, uncertain information, and market efficiency, Journal of Financial Economics 22, 355-385.

Brusa, J. P. Liu, and C. Schulman (2000), The Weekend Effect, Reverse Weekend Effect, and Firm Size, Journal of Business Finance and Accounting, 27 (5 and 6), 555-574.

Burghardt G., and Hanweck, G. (1993), Calendar-Adjusted Volatilities, Journal of Derivatives

Cadsby, C. B., and Ratner, M. (1992), Turn-of-month and pre-holiday effects on stock returns: some international evidence, Journal of Banking and Finance 16 (3), 497-509.

Cai, J., Yan-Leung C., Raymond S.K., and Melvin, M. (2001), Once in a generation Yen Volatility in 1998: Fundamentals, Intervention and Order, Journal of International Money and Finance, 20, 327-347.

Campbell, J. Y., (1987), Stock Returns and the Term Structures, Journal of Financial Economics, 18, 373 – 399.

Campbell, J. Y., and Shiller, R. (1988), Stock Prices, Earnings, and Expected Dividends, Journal of Finance, 43, 661 – 676.

Campbell, J. Y. (1991), A Variance Decomposition of Stock Returns, Economic Journal, 101, 157 – 179.

Campbell, J. and Hentschel, L. (1992), No News is Good News: An Asymmetric Model of Changing Volatility in Stock Returns, Journal of Financial Economics, 31, 281-331.

Campbell, J. Y., Lo A. W., and MacKinlay C. (1997), The Econometrics of Financial Markets, Princeton University Press: Princeton

Canina, L. and Figlewski, S. (1993), The Information Content of Implied Volatility, journal Review of Financial Studies, 6(3), 659-681

Carlson, J. (2002), One minute in the life of the DM/USD: public information in an electronic market. Typescript, Purdue University, August.

Carlson, J. A. and Osler, C. L. (2000), Rational Expectations and Exchange Rate Volatility, European Economic Review, 44, 231-253.

Castren, O. and Mazzotta, S. (2005), Foreign exchange option and returns based correlation forecasts: Evaluation and two applications, Working paper series No. 447/February 2005, European Central Bank

Chaboud, A., and Weinberg, S. (2005), Foreign exchange markets in the 1990s: Intraday market volatility and the growth of electronic trading, Board of Governors of the Federal Reserve System.

Chan, K.C. (1985), Can tax-loss selling explain the January seasonal in stock returns?, Working Paper, Ohio State University.

Chan, K., Chan K.C. and Karolyi, A. (1991), Intraday Volatility in the Stock Index and Stock Index Futures Markets, The Review of Financial Studies, 4(5), 657 – 684.

Chan, K. C., Karolyi A., and Stulz, R. (1992), Global Financial Markets and the Risk Premium on US equity, Journal of Financial Economics 32, 137 – 167.

Chan, K., Chung, P., and Johnson, H. (1993), Why Option Prices Lag Stock Prices: A Trading Based Explanation, Journal of Finance, 48, 1957-1968.

Chan, A., and Kwok, C. (2001), The impact of salient political and economic news on the Trading activity, Pacific-Basin Finance Journal, 9, 195-217.

Chang, E (1988), A monthly effect in commodity price changes: A note, Journal of Futures Markets, 8, 717-722.

Chang, E. C., Pinegar, J. M. and Ravichandran, R. (1993), International evidence on the robustness of the day-of-the-week effect, Journal of Financial and Quantitative Analysis 28, 497–514.

Chang, E., Pinegar, M., and Schachter, B. (1997), Interday variations in volume, variance, and participation of large speculators, Journal of Banking and Finance, 21, 797–810.

Chang, E. C., Pinegar, J. M., and Ravichandran, R. (1998), US day-of-the-week effects and asymmetric responses to macroeconomic news, Journal of Banking and Finance, 22, 513-534.

Chang, Y. and Taylor, S. T. (2001), Information Arrival and Intraday exchange rate volatility, Journal of International Financial Markets, Institutions and Money, 13, 2, 85-112.

Chao, C. and Zhong-Guo, Z. (2001), Portfolio Returns, Market Volatility, and Seasonality, Review of Quantitative Finance and Accounting, 17, 1-27.

Cheung, Y. W., Chinn, M. D. (2001), Currency traders and exchange rate dynamics: a survey of the U.S. market. Journal of International Money and Finance 20, 439–471.

Chong R., Hudson R., Keasey K., Littler K. (2005), Pre Holiday Effect: International evidence on the decline and Reversal of a stock market anomaly, Journal of International Money and Finance, 24, 1226-1236.

Choy, A. Y. F. and O'Hanlon, J. (1989), Day-of-the-week effects in the UK equity market: A cross-sectional analysis, Journal of Business Finance and Accounting, 16, 89–104

Chow, E., Hsiao, P. and M. Solt (1997), Trading Returns for the Weekend Effect Using Intraday Data, Journal of Business Finance and Accounting, 24 (3&4), 425-444.

Christie, A.A., (1982), The Stochastic Behavior of Common Stock Variances - Value, Leverage and Interest Rate Effects, Journal of Financial Economics, 3, 145-166.

Chukwuogor – Ndu, C. (2006), Stock Market Returns Analysis, Day of the Week Effect, Volatility of Returns: Evidence from European Financial Markets 1997 – 2004, International Research Journal of Finance and Economics, Issue 1.

Clare, A., Psaridakis, Z. and Thomas, S. (1995), An analysis of seasonality in the UK equity market, The Economic Journal, 105, 398–409.

Cohen, D., (1997), How Will the Euro Behave?, in Masson, P. R., Krueger, T. S. and Turtelboom, B. G., EMU and the International Monetary System, International Monetary Fund.

Conrad, J., Cornell, B. and Landsman, W. (2001), When is Bad News Really Bad News?, Working Paper, University of North Carolina, Chapel Hill.

Commission of the European Communities, (1990), One Market, One Money: An Evaluation of the Potential Benefits and Costs of Forming an Economic and Monetary Union, European Economy, 44.

Compton William (2002), The Evolving Turn-of-the-Month Effect: Evidence from Pacific Rim Countries, University of North Carolina – Wilmington.

Condoyanni, I., O'Hanlon, J. and Ward, C. W. R. (1987), Day of the Week Effects on Stock Returns: International Evidence, Journal of Business Finance and Accounting, 14, 2, 159-174.

Connolly, R.A., (1989), An examination of the robustness of the weekend effect, Journal of Financial and Quantitative Analysis 24, 133-169.

Connolly, R.A. (1991), A posterior odds analysis of the weekend effect, Journal of Econometrics 49, 51-104.

Conrad, J. and Kaul, G., (1993), Long-term market overreaction or bias in computed returns, Journal of Finance, March, 39-64.

Copeland, L. S. and Wang, P. (1994), Estimating Daily Seasonality, Journal of Forecasting, 13 (6), 519.

Coppel, J., Durand, M. and Visco, I., (2000), The European Monetary Union, the Euro, and the European Policy Mix, Journal of Asian Economics, Vol. 11, 31-63.

Corhay Albert, Gabriel Hawawini and Pierre Michel (1987), Seasonality in the Risk-Return Relationship: Some International Evidence, The Journal of Finance, 42, 49–68.

Corhay, A., Fatemi, A., and Rad, A. T. (1995), On the presence of a day-of-the-week effect in the foreign exchange market, Journal of Managerial Finance, 21, 32-43.

Cornell, B. (1985), The Weekly Pattern in Stock Returns: Cash versus Futures: A Note, Journal of Finance, 40, 583-588.

Cornell, B. (1983), The Money Supply Announcements Puzzle: Review and Interpretation, American Economic Review, September 1983, 73, 644 -657.

Cornett M. M., Thomas V. S. and Szakmary, A. C. (1995), Seasonalities and intraday return patterns in the foreign currency futures market, Journal of Banking & Finance, 19 (5), 843-869.

Corsetti, G. and Pesenti, P. (1999), Stability, Asymmetry and Discontinuity: The Launch of European Monetary Union, Brookings Papers on Economic Activity, 295-358.

Cross, F. (1973), The Behavior of Stock Prices on Fridays and Mondays, Financial Analysts Journal, 67- 69.

Coutts, J.A., Kaplanidis, C., and Roberts, J. (2000), Security price anomalies in an emerging market: the case of the Athens stock exchange, Applied Financial Economics, 10 (5), 561-571.

Cutler, D.M., Poterba, J.M., and Summers, L.H. (1989), What moves stock prices?, Journal of Portfolio Management, 15, 4-12.

Cyr D. and Tanya, L. (1994), A Time Series Test of Calendar Seasonalities in the S&P 100 Index since the Introduction of Index Derivative Securities, The Journal of Futures Markets (1986-1998), Aug. 1994.

Cyree, K., and Winters, D. (2001), An intraday examination of the federal funds market: Implications for the theories of the reverse-J pattern, Journal of Business, 74, 535–556.

Cyree, K., Mark D., G., and Winters, D. B. (2004), An empirical examination of the intraday volatility in euro–dollar rates, The Quarterly Review of Economics and Finance, 44 (2004), 44–57

Dacorogna, M., Muller, U. A., Nagler, R. J., Olsen, R., and Pictet O. V. (1993), A geographical model for the daily and weekly seasonal volatility in the FX market, Journal of International Money and Finance, 1, 413-438.

Damodaran, A. (1985), Economic Events, Information Structure, and the Return-generating Process, The Journal of Financial and Quantitative Analysis, 20 (4).

Damodaran, A. (1989), The weekend effect in information releases: A study of earnings and dividend announcements. Review of Financial Studies 2, 607-623.

Daniel K. and Marshall, D. (1997), Consumption-based modeling of long horizons returns, Macroeconomic Dynamics, 1, 452 – 484.

David, A. and Veronesi, P. (2001), Inflation and Earnings Uncertainty and the Volatility of Asset Prices: An Empirical Investigation, Working Paper.

Davidson, W. N., Kim, K. J., Ors, E., and Szakmary, A. (2001), Using Implied Volatility on Options to Measure the Relation Between Asset Returns and Variability, Journal of Banking and Finance, 25, 1245 – 1269.

Day, T. E., and Lewis, C. M. (1992), Stock Market Volatility and the Information Content of Stock Index Options, Journal of Econometrics, 52 (1&2), 267-288.

Day, T. E., and Lewis, C. M. (1994), Forecasting Futures Market Volatility, Journal of Derivatives, 1 (2), 33-50.

Debondt, W. F. M. and Thaler, R. (1985), Does the stock market overreact?, Journal of Finance, 40, 793–808.

DeGennaro, R. and Shrieves, R. E. (1997), Public information releases, private information arrival and volatility in the FX market, Journal of Empirical Finance, 4, 295-315.

Deravi, K., Gregorowicz, P., and He, C. E. (1988), Balance of trade announcements and movements in exchange rates, Southern Economic Journal, 55, 279-287.

Diebold F.X. (1988), Empirical modeling of exchange rate dynamics. In: Lecture notes in economic and mathematical systems 303, Springer, Berlin.

Dimitrios Angelidis and Katerina Lyroudi (2004), Seasonalities in the French Stock Market: The day of the Week Anomaly, 11th Annual Conference of the Multinational Finance Society, July 3-8, 2004, Istanbul, Turkey.

Draper, P. and Paudyal, K. (1997), Microstructure and seasonality in the UK equity market, Journal of Business Finance and Accounting, 24, 1177–1204.

Dominguez, K. M. (1990), Market responses to coordinated Central Bank intervention, Carnegie Rochester Series on Public Policy, 32, 121-163.

Dominguez, K. M. and Frankel, J. A. (1993), Does FX Intervention Work?, Institute for International Economics, Washington DC.

Dominguez, K. M. (1993), Does Central Bank intervention increase the volatility of FX rates?, NBER Working Party No. 4532.

Dominguez, K.M. (1998), Central bank intervention and exchange rate volatility, Journal of International Money and Finance, 17, 161-190.

Dominguez, K. M. (2003), The market microstructure of central bank intervention, Journal of International Economics, 59, 25-45.

Dominquez, K. M. (2004), When Do Central Bank Interventions Influence Intra-daily and Longer-Term Exchange Rate Movements, Journal of International Money and Finance, 25, 1051-1071.

Dominguez, K. M. and Panthaki, F. (2005), What defines "News" in Foreign Exchange Market?, International Policy Centre, Gerald R. Ford School of Public Policy, University of Michigan, IPC Working Paper Series Number 2.

Donders, M. and Vorst, T. (1996), The Impact of Firm Specific News on Implied Volatilities, Journal of Banking and Finance, 20 (9), 1447-1461.

Dornbusch, R. (1975), A portfolio balance model of the open economy, Journal of Monetary Economics, 1, 3-20.

Dubois M. and P. Louvet (1996), The day of the week Effect: The International Evidence, Journal of Banking and Finance, 20, 1463-1484.

Dumas, B., Fleming, J. and R. Whaley (1998), Implied Volatility Functions: Empirical Tests, Journal of Finance, 53, 2059-2106.

Dyl, E.A. (1977), Capital gains taxation and year-end stock market behavior, Journal of Finance, 32, 165-175.

Dyl E.A. (1977), In: Profits and Patterns in the Federal Funds Market, Burroughs Clearing House, 60–62.

Dyl E.A. and Maberly E.D. (1986), The daily distribution of changes in the price of stock index futures, Journal of Futures Markets, 6, 513–521.

Easley, D., O'Hara, M. (1992), Time and the Process of Security Price Adjustment, Journal of Finance, XLVII (2), 577-605.

Eddelbuttel, Dirk and Thomas H. McCurdy (1998), The Impact of News on FX Rates: Evidence from High Frequency Data, Rotman School of Management and Institute for Policy Analysis, University of Toronto, Working Paper

Ederington, L., and Lee, J. (1993), How markets process information: news releases and volatility, Journal of Finance, 9, 1161–1198.

Ederington, L., and Lee, J., (1995), The Short Run Dynamics of the Price Adjustment to New Information, Journal of Financial and Quantitative Analysis, 30, 117- 134.

Ederington and Lee, H. (1996), The Creation and Resolution of Market Uncertainty: the Impact of Information Releases on Implied Volatility, Journal of Financial Economics, 31 (1), 513 – 539.

Ederington and Lee (2001), Intraday Volatility in Interest Rate and Foreign Exchange Markets: ARCH, Announcement, and Seasonality Effects, The Journal of Futures Markets, 21 (6), 517.

Edison, H. (1997), The reaction of exchange rates and interest rates to news releases, International Journal of Finance and Economics, 2, 87-100.

Eichengreen, B. (1998), The Euro as a Reserve Currency, Journal of the Japanese and International Economies, 12, 483-506.

Eichengreen, B. (2000), The Euro One Year On, Journal of Policy Modeling, 22, 355-68.

Engle, R. F. and Bollerslev, T. (1986), Modeling the Persistence of Conditional Variances, Econometric Reviews, 5, 1-50.

Engle, R.F., Lilien D.M., and Robins, R.P. (1987), Estimating time varying risk premium in the term structure: the ARCH-M model, Econometrica, 55, 391–407.

Engle, R. (1993), Statistical models for financial volatility, Financial Analysts Journal, 72-78.

Engle, R. F. and Ng, V. K. (1993), Measuring and Testing the Impact of News on Volatility, Journal of Finance, 48, 1749-1778.

Evans, M. D., and Lyons, R. (1999), Order flow and exchange rate dynamics, University of Berkeley Working paper.

Evans, M. D. (2002), FX trading and exchange rate dynamics, Journal of Finance, 57, 2405–2448.

Evans, M. D. and Lyons, R. K. (2003), How is macro news transmitted to exchange rates? NBER Working Paper 9433.

Evans, M. D. and Lyons, R. K. (2004), A new micro model of exchange rate dynamics, NBER Working Paper, 10379.

Evans, M. D. and Lyons, R. (2005), Do currency markets absorb news quickly?, Journal of International Money and Finance, 24, 197–217.

Fabozzi, F. J., Briley, J. E. (1994), Holiday trading in futures markets, Journal of Finance, 44 (1), 307-324.

Fama, E. (1965), The Behavior of Stock Market Prices, Journal of Business, 38, 34-105.

Fama, E. (1970), Efficient capital markets: A review of the theory and empirical work, Journal of Finance, 25, 383-417.

Fama E. and French, K. R. (1988), Permanent and Temporary Components of Stock Prices, Journal of Political Economy, 96, 246-273.

Fama E. and French, K. R. (1989), Business Conditions and Expected Stock Returns, Journal of Financial Economics, 25, 23 – 49.

Fang, Y. (2000), Seasonality in FX Volatility, Journal of Applied Economics, 32, 697-703.

Farmer D. and Joshi, S. (2002), The price dynamics of common trading strategies, Journal of Economic Behaviour and Organization, 49, 149-171.

Feinstein, S. (1989), The Black and Scholes Formula is nearly linear for at-the-money options; therefore implied volatilities from at-the-money options are virtually unbiased, Working paper, Federal Reserve Bank of Atlanta.

Fergusson, M. F., Mann, S. C., and Schneck, L. J. (1998), Concentrated trading in the foreign exchange futures markets: Discretionary liquidity trading or market closure? The Journal of Futures Markets, 18 (3), 343–362.

Ferris, S., Weiyu G. and Tie S. (2003), Predicting Implied Volatility in the Commodity Futures Options Markets, CiteSeer Online Paper.

Ferson, W. E., and Harvey, C. R. (1991), The variation of economic risk premiums, Journal of Financial Economics 25, 23-49.

Fields, M. J. (1934), Security Prices and Stock Exchange Holidays in Relation to Short Selling, Journal of Business, 7, 328–338.

Figlewski, S. (1997), Forecasting volatility. In: Financial Markets, Institutions, and Instruments, Boston MA: Blackwell Publishers, 6(1).

Fischer, A. and Zurlinden, M. (1999), Exchange Rate Effects of Central Bank Interventions: An Analysis of Transaction Prices, Economic Journal, 109, 662-676.

Fischer, A. M. (2005), On the Inadequacy of Newswire Reports for Empirical Research On Foreign Exchange Interventions, Swiss National Bank Working Papers 2005-2.

Fishe, R. P., Gosnell, T. F. and Lasser, D. J. (1993), Good news, bad news, volume and the Monday effect, Journal of Business Finance and Accounting 20, 881–892.

Flannary, A. and Propapadakis, A. (1988), From T-bills to common stocks: investigating the generality of intra-week return seasonality, Journal of Finance, 431-449.

Fleming, J., Osttidek, B. and Whaley, R. R. (1995), Predicting stock market volatility: A New Measure, Journal of Futures Markets, 15 (3), 265 – 302.

Fleming, J., Ostdiek, B., and Whaley, R. (1995), The Integration of Stock, Futures and Option Market Returns, Working Paper, Duke University.

Fleming, M., and Remolona, E. (1997), What moves the bond market? In: Economic Policy Review, Federal , Reserve Bank of New York, New York, NY, 31–50, December.

Fleming, M. J. and Remolona, E. M. (1999), Price formation and liquidity in the U.S. treasury market: The response to public information, Journal of Finance, 54, 1901– 1915.

Flood, R. P. and Rose, A. K. (1995), Fixing Exchange Rates: A Virtual Quest for Fundamentals, Journal of Monetary Economics, 36, 3-37.

Fortune, P. (1998), Weekends Can Be Rough: Revisiting the Weekend Effect in Stock Prices. Federal Reserve Bank of Boston Working Paper 98-6.

Fosback, N. (1976), Stock Market Logic: A Sophisticated Approach to Profits on Wall Street. Institute for Econometric Research, Fort Lauderdale, FL.

Foster, F. D., and Viswanathan, S. (1990), A Theory of the Interday Variations in Volume, Valance and Trading Costs in Securities Markets, Review of Financial Studies, 3, 593-624.

Foster, F. D. and Viswanathan, S. (1993), Variations in Trading Volume, Return Volatility, and Trading Costs: Evidence on Recent Price Formation Models, Journal of Finance, 48, 187 -211.

Foster, F. D. and Viswanathan, S. (1995), Can speculative trading explain the volume-volatility relation?, Journal of Business Economic Statistics, 13, 379-396.

Frankel, J. A. and Rose, A. K., (1997), Is EMU More Justifiable Ex Post than Ex Ante?, European Economic Review, 41, 753-760.

Franks, J. (2002), How has the Euro Changed the FX Market: Discussion, Economic Policy, 34, 180-182.

French, D. (1980), Stock Returns and the Weekend Effect, Journal of Financial Economics, 8(1), 55-69

French, D. (1984), The Weekend Effect on the Distribution of Stock Prices – Implications for Option Pricing, Journal of Financial Economics, 13(4), 547-559

French, D. and Roll, R. (1986), Stock returns variances: The arrival of information and the reaction of traders, Journal of Financial Economics, 17, 5– 26.

Frenkel, M., Pierdzioch, C. and Stadtmann, G. (2003), The Effects of Japanese FX Market Interventions on the Yen/US Dollar Exchange Rate Volatility, International Review of Economics and Finance, 14(1), 27-39.

Froot, K. A., Scharfstein, D. S. and Stein, J. C. (1992), Heard on the street: Informational inefficiencies in a market with short-term speculation, Journal of Finance, 47, 1461-1484.

Fung H., Lie, C. and Moreno, A. (1990), The forecasting performance of the implied standard deviation in currency options, Journal of Managerial Finance, 16, 3, 24-29.

Fung, W., Hsieh, D. (1991), Estimating the dynamics of foreign currency volatility, Review of Futures Markets, 491–514.

Galati, G. and Melick, W. (1999), Perceived central bank intervention and market expectations: an empirical study of the yen/dollar exchange rate, Working Paper No. 77, Bank for International Settlements, Basel.

Gay G. and Kim, T. (1987), An Investigation into Seasonality in the Futures Market, The Journal of Futures Market, 7, 169-181.

Gardeazabal, J. and Regulez, M. (2002), The Weekend-Dividend Effect in the Spanish Market, Presentation at the 2002 European Finance Management Association, Annual Conference, London, UK.

Gesser and P. Poncet (1997), Volatility Patterns: Theory and dome Evidence from the dollar-mark option market, Journal of Derivatives, 5, 46-61.

Gibbons, M. and Hess, P. (1981), Day of the week effects and asset returns. Journal of Business, 54, 579–596.

Giot, Pierre (2005), On The Relations Between Implied Volatility Indices and Stock Index Returns, Journal of Portfolio Management, 2005, 31, 92-100

Givoly, D. and Ovadia, A. (1983), Year-End Tax-Induced Sales and Stock Market Seasonality, Journal of Finance, 38, 171–185.

Ghysels, E., Santa-Clara, P. and Valkanov, R. (2005), There is a Risk-Return Tradeoff After All, Journal of Financial Economics, 76 (3), 509-548.

Glassman, D. (1987), Exchange rate risk and transactions costs: Evidence from bid-ask spreads, Journal of International Money and Finance 6, 479-490.

Glosten, L. R., Jagannathan, R. and Runkle, D. E. (1993), On the Relation Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks, Journal of Finance, 48, 1779-1801.

Goodhart, C. and Figliuoli, L. (1992), The geographical location of the FX market: A test of the island hypothesis, Journal of International and Comparative Economics, 1, 13-28.

Goodhart, C. and Pesaran, H. (1993), News Effects in a High-Frequency Model of the Sterling-Dollar Exchange Rate, Journal of Applied Econometrics, 8, 1-13.

Goodhart, C. and O'Hara, M. (1997), High frequency data in financial markets: Issues and Applications, Journal of Empirical Finance 4, 73-114.

Grassman, S. (1973), A fundamental symmetry in international payment patterns, Journal of International Economics, 3, 105-116.

Grossman, J. (1981), The 'rationality' of money supply expectations and the short-run response of interest rates to monetary surprises, Journal of Money, Credit and Banking, 13, 409-424.

Gu, Y. A. (2003), The Declining January Effect: Evidences from the U.S. Equity Markets, Quarterly Review of Economics and Finance, 395.

Gultekin, M. and Gultekin, N. B. (1983), Stock market Seasonality, Journal of Financial Economics, 12, 469-481.

Guo, D. (1996), The predictive power of implied stochastic variance from currency options, Journal of Futures Markets, 16 (8), 915-942.

Guo, D. (1996), The information content of implied stochastic volatility from currency options, Canadian Journal of Economics, 29, 559-561.

Guo, H. and Faff, R. (2003), Uncovering the Risk-Return Relation in the Stock Market, NBER Working Paper No. W9927.

Guo, D. (2003), Dynamic Volatility Trading Strategies in the Currency Option Market Using Stochastic Volatility Forecasts, Review of Derivatives Research, 4((2), 133-154.

Hansen, L. P. (1982), Finite-sample properties of some alternative GMM estimators. Journal of Business and Economic Statistics , 14(3), 262-281.

Hakkio, C. and Pearce, D. (1985), The reaction of exchange rates to economic news. Economic Inquiry, 23, 621-635.

Han, L., Kling, J. L. and Sell, C. W. (1998), FX futures volatility: Day-of-the-week, intraday, and maturity patterns in the presence of macroeconomic announcements, Journal of Futures Markets, 19 (6), 665 – 693.

Hardouvelis, G. (1987), Macroeconomic information and stock prices. Journal of Economics and Business, 39, 131-140.

Hardouvelis, G. A. (1988), Economic News, Exchange Rates and Interest Rates, Journal of International Money and Finance, 7, 23-35.

Harris, L. (1986), A transactions data study of weekly and intraday patterns in stock returns, Journal of Financial Economics, 16, 99-117.

Harris, L. (1987), Transaction data tests of the mixture of distributions hypothesis. Journal of Financial and Quantitative Analysis, 22, 127–141.

Harris, L. (1989), The October 1987, S&P 500 stock-futures basis, Journal of Finance, 44.

Harris, M. and Raviv A. (1993), Difference of Opinion Make a Horse Race, Review of Financial Studies, 6, 473 – 506.

Harrison, P. and Harold Z. H. (1998), An Investigation of the Risk and Return Relation at Long Horizons , Review of Economics and Statistics, 81 (3), 399-408.

Hartmann, P. (1998), Currency Competition and Foreign Exchange Markets, Cambridge University Press, European Central Bank Paper.

Harvey, Campbell (2001), The specification of conditional expectation expectations, Journal of Empirical Finance, 8, 573 – 638.

Harvey, C. R., and Huang, R. D. (1991), Volatility in the FX currency market, Review of the Financial Studies, 4, 543–569.

Harvey, C. and Whaley, R. (1991), S&P 100 index option volatility, Journal of Finance, 46, 1551-1561.

Harvey, C. R., and Huang, R. D., (2002), The Impact of the Federal Reserve Bank's Open Market Operations, Journal of Financial Market, 5, 223 – 257.

Harvey and Whaley (1992), Market Volatility Prediction and the Efficiency of the S&P 100 Index option Market, Journal of Financial Economics 31 (1), 43 – 74.

Hasbrouck, J. and Sofianos, G. (1993), The trades of market makers: an empirical analysis of NYSE specialists, Journal of Finance, 48, 1565-1593.

Hau, H. (1998), Competitive Entry and Endogenous Risk in the Foreign Exchange Market, Review of Financial Studies, 11, 757-787.

Haugen, R. A. and J. Lakonishok (1988), The Incredible January Effect, Dow Jones-Irwin, Homewood.

Haugen, R.A., Talmor, E. and Torous, W. N. (1991), The effect of volatility changes on the level of stock prices and subsequent expected returns. Journal of Finance, 46, 985-1007.

Haugen, R. and Jorion, P. (1996), The January Effect: Still There After All These Years, Financial Analysts Journal, 52 (1), 27-31.

Hayne, L. and Rubinstein, M. (1988), Comments on the Market Crash: Six Months After. Journal of Economic Perspectives, 2, 45–50.

Heaney, R. and Swieringa, J. (2003), European Currency Volatility After Economic and Monetary Union, School of Finance and Applied Statistics, Australian National University, Working Paper.

Hensel, R. and Ziemba, W. (1996), Investment Results from Exploiting TOM Effects, Journal of Portfolio Management, 22 (3), 17-23.

Heynen, R., Kemna K. and Vorst T. (1994), Analysis of the Term Structure of Implied Volatilities, Journal of Financial and Quantitative Analysis, 29, 31-56.

Hilliard, J. E. and Tucker, A. L. (1992), A note on weekday, intraday, and overnight patterns in the interbank foreign exchange and listed currency options markets, Journal of Banking and Finance 16, 1159-1171.

Hillier, D. and Marshall, A. (2002), Insider trading, tax-loss selling, and the turn-of-the-year effect, International Review of Financial Analysis, 11, 73–84.

Hirsch, Y. (1979), Stock trader's almanac, The Hirsch Organization, Old Tappen, NJ

Ho, R. and Siu-kuen, R. L. (1998), Market closure effects on return, volatility, and turnover patterns in the Hong Kong index futures market, Journal of International Financial Markets, Institutions and Money, 8, 433–451.

Hogan, K. and Melvin, M. (1994), Sources of meteor showers and heat waves in the foreign exchange market. Journal of International Economics, 37, 239-247.

Hogan, K., Melvin, M. and Roberts, D. (1991), Trade balance news and exchange rates: is there a policy signal? Journal of International Money and Finance, 10, S90-S99.

Honohan, P. (2002), How has the Euro Changed the FX Market: Discussion, Economic Policy, 34, 177-180.

Howe, J. S. and Wood, B. G. (1993), An Investigation of Calendar Anomalies in Pacific Rim and U.S. Equity Markets. In: Theodore Bos, Editor, Research in the Financial Markets of the Pacific Basin, JAI Press.

Hsieh, D. A. (1988), The statistical properties of daily foreign exchange rates: 1974-1983, Journal of International Economics, 24, 129-45.

Hsieh, D. A. and Kleidon, A. W. (1996), Bid-ask spreads in foreign exchange markets: implications for models of asymmetric information. In: Frankel, J. (Ed.), The Microstructure of Foreign Exchange Markets. University of Chicago Press, Chicago, 41–65.

Hull, John and Alan White (1987), The Pricing of Options on Assets with Stochastic Volatility, Journal of Finance, 42 (2), 281-300.

Humpage, O. (1998), US Intervention: assessing the probability of success, Federal Reserve Bank of Cleveland Working Paper 9608, January.

Humpage, O. F. (2003), Government Intervention in the Foreign Exchange Market, Federal Reserve Bank of Cleveland, Working Paper 03-15.

Hussain, Fazal (1998), A seasonality in the Pakistani Equity Market: the Ramadan effect, The Pakistani Development, 77-81.

Ittenback, R. Chayer D., Bruininks, R., Thurlow, M. and Beirne-Smith M. (1993), Adjustment of young adults with mental retardation in community settings: comparison of parametric and nonparametric techniques, American Journal of Mental Retardation, 97, pp. 607-615

Ito, T., Lyons, R. K., Melvin, M. T., Is there private information in the FX market?, The Tokyo experiment, Journal Finance, 53, 1113–1132.

Ito, T., Roley, V. V. (1987), News from the U.S. and Japan: which moves the yen/dollar exchange rate?, Journal of Monetary Economics, 19, 255-277.

Ito, T. and Hashimoto, Y. (2006), Intraday Seasonality in Activities of the Foreign Exchange Markets: Evidence from the electronic broking system, The Journal of Japanese and International Economics

Jacobs, B. I. and Levy, K. N. (1988), Calendar Anomalies: Abnormal Returns at Calendar Turning Points, Financial Analysts Journal, 44, 28–39.

Jaffe, J. F. and Westerfield, R. (1985), The week-end effect in common stock returns: the international evidence. Journal of Finance, 40, 433–454.

Jaffe, J. and Westerfield, R. (1989), Is There a Monthly Effect in Stock Market Returns?: Evidence from Foreign Countries, Journal of Banking and Finance, 13 (2), 237-244.

Jayaraman N., Mandelker and Shastri (1984), Market Anticipation of Merger Events: An Empirical Test, Working paper No. 583, University of Pittsburgh.

Jorion, P. (1995), Predicting volatility in the FX market, Journal of Finance, 50, 2, 507-528.

Johnson, T. C. (2000), Return Dynamics When Persistence is Unobservable, Manuscript, London Business School.

Johnson, T. C. (2001), Volatility, Momentum, and Time Varying Skewness in FX Returns, Manuscript, London Business School.

Johnston, E., Kracaw, W. and McConnell, J. (1991), Day of the Week effects in financial futures: An analysis of GNMA, T-bond, T-note, and T-bill contracts, Journal of Financial and Quantitative Analysis, 26, 23-44.

Jones, C. P., Pearce D. K., and Wilson, J. W. (1987), Can Tax-Loss Selling Explain the January Effect? A Note, Journal of Finance, 42, 453-461.

Jones L. S. and Singh, K. M. (1997), The Distribution of Stock Returns Implied in Their Options at the Turn of the Year: A Test of Seasonal Volatility, The Journal of Business, 70 (2), 281.

Jones, C. M., Lamont, O. and Lumsdaine, R. L. (1998), Macroeconomic news and bond market volatility, Journal of Financial Economics, 47, 315–337.

Jones, S. L., Winson, L. and Rudolf, A. (1991), New Evidence on the January Effect Before Personal Income Taxes, The Journal of Finance 46, 1909–1924.

Jordan, S. and B. Jordan (1991), Seasonality in Daily Bond Returns, Journal of Financial and Quantitative Analysis, 26 (2), 269-285

Jorion P. (1996), Risk and turnover in the FX market, in Frankel J.A., G. Galli and A. Giovannini ed. The Microstructure of FX Markets, Chicago: The University of Chicago Press.

Kamara, A. (1995), New evidence on the Monday seasonal in stock returns, Working paper, University of Washington.

Kaminski, G. L. and Lewis, K. (1993), Does FX intervention signal future monetary policy?, NBER Paper No. 4298.

Kandel, S. and Stambaugh, R. F. (1990), Expectation and Volatility of Consumption and Asset Returns, Review of Financial Studies, 3, 207 – 332.

Kato, K. (1990), Weekly patterns in Japanese stock returns. Management Science, 36, 1031–1043.

Kawaller, I. G., Koch, P. D. and Koch, T. W. (1993), Intraday market behavior and the extent to feedback between S&P 500 futures prices and the S&P 500 Index, Journal of Financial Research, 16, 107-121.

Kearns, J., and Rigobon R. (2004), Identifying the Efficacy of Central Bank Interventions: Evidence from Australia and Japan, Journal of International Economics, 66(1), 31-48.

Keim, D. B. (1983), Size-related anomalies and stock return seasonality: Further empirical evidence, Journal of Financial Economics 12, 13-32.

Keim, D. B. (1989), Trading patterns, bid-ask spreads and estimated security returns: the case of common stocks at calendar turning points, Journal of Financial Economics, 25 (1), 75-97.

Keim, D. and Stambaugh, R. (1984), A Further Investigation of the Weekend Effect in Stock Returns, Journal of Finance, 819- 837.

Keim, Donald B. and Robert F. Stambaugh (1986), Predicting returns in the stock and bond markets, Journal of Financial Economics 17, 357 – 390.

Kenourgios, D. (2006), The Day of the Week Patterns on Stock Market Return and Volatility: Evidence for the Athens Stock Exchange, EconWPA Finance Paper 0512028.

Killeen, W. P., Lyons, R. K. and Moore, M. J. (2001), Fixed Versus Flexible: Lessons from EMS Order Flow, NBER Working Paper Series, No. 8491.

Killeen, H. H. W. and Moore, M. (2002), How has the Euro Changed the FX Market, Economic Policy, 34, 151-91.

Killeen, H. H. W. and Moore, M. (2002), The Euro as an International Currency: Explaining Puzzling First Evidence from the FX Markets, Journal of International Money and Finance, 21, 351-383.

Kim, S.-J. (1999), Do macroeconomic news announcements affect the volatility of FX rates? Some evidence from Australia, Journal of Applied Economics, 31, 1511–1521.

Kim, S., McKenzie, M. D. and Faff, R. F. (2004), Macroeconomic news announcements and the role of expectations: evidence for US bond, stock and FX markets, Journal of Multinational Financial Management, 14, 217–232.

Kim, M. and Kim M. (2004), Implied Volatility Dynamics in the FX Markets, Journal of International Money and Finance, 22, 511–528.

Kim, S. W. (1988), Capitalizing on the Weekend Effect, Journal of portfolio Management, 15, 61-64.

Kim, C. and Park, J. (1994), Holiday effects and stock returns: further evidence, Journal of Financial and Quantitative Analysis, 29 (1), 145-157.

King, M. A., Wadhwani, S. (1990), Transmission of volatility between stock markets, Review of Financial Studies, 3, 5-33.

Kohers, T. and Kohers, G. (1995), The Impact of Firm Size Differences on the Day of the Week Effect: A Comparison of Major Stock Exchanges, Applied Financial Economics, 5, 151-60.

Koulakiotis, A., Papasyriopoulos, N. and Molyneux, Phil (2006), More Evidence on the Relation between Stock Price Returns and Volatility: A Note, International Research Journal of Finance and Economics, 1, 21-28.

Krugman. P., and Obstfeld, M. (1988), International Economics, Scott Foresman, Glenview, 111.

Kunkel, R. and Compton, W. (1998), A tax free exploitation of the TOM effect: CREF, Financial Services Review, 7, 11-23.

Kunkel, R., Compton, W., and Beyer, S. (2003), The turn of the month effect still lives: the International Evidence, International Review of Financial Analysis, 12, 207-221.

Kuttner, K. N. (2001), Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market, Journal of Monetary Economics, 47, 523-544.

Kuserk, G. J., Locke, P. R. (1993), Scalper behavior in futures markets: an empirical examination, Journal of Futures Markets, 13, 40-431.

Laakkonen, H. (2004), The impact of macroeconomic news on exchange rate volatility, Bank of Finland Discussion Papers, Bank of Finland Discussion Paper 24/2004.

Lakonishok, J. and Levi, M. (1982), Weekend effect in stock return: A note, Journal of Finance, 37, 883–889.

Lakonishok, J. and Smidt S. (1984), Volume and Turn-of-the-Year Behavior, Journal of Financial Economics, 13, 435-456.

Lakonishok, J. and Seymour S. (1986), Capital gain taxation and volume of trading, Journal of Finance, 41, 951 -976.

Lakonishok J. and Maberly, E., (1990), The weekend effect: Trading patterns of individual and institutional investors, Journal of Finance, 45, 231-243.

Lamoureux, C. and Lastrapes W. (1994), Endogenous Trading Volume and Momentum in Stock Return Volatility, Journal of Business and Economic Statistics, 12, 253-260.

Latane and Rendleman (1976), Standard Deviations of Stock Price Ratios Implied in Option Prices, Journal of Finance, 31, 369-381.

Laubsch, A. J. (1999), Risk management: a practical guide, RiskMetrics Group.

Lee, I., Pettitt, R., and Swankowski, M. (1990), Daily Return Relationships among Asian stock Markets, Journal of Business Finance and Accounting, 17, 265 - 284 .

Leng, H. H. (1996), Announcement vs. Non-announcement: A study of intraday transaction price of Deutsche mark and Japanese yen futures, The Journal of Futures Markets, 16 (7), 829–857.

Levi, M. (1988), Weekend Effects in Stock Market Returns: An Overview, in Elroy Dimson Stock Market Anomalies (Cambridge University Press, Cambridge).

Lewis, K. (1994), Puzzles in international Financial markets, NBER Working Paper No. 5505, March.

Liano, K., Marchand, P.H., and Huang, G. (1992), The holiday effect in stock returns: evidence from the OTC market, Review of Financial Economics 2 (1), 45-54.

Liano, K. (1995), A pre holiday Effect in the Currency Futures Market: A Note, International Review of Economics and Finance, 4(3), 299-304.

Liano K. and Kelly W. (1995), Currency Futures and the Turn of the Month Effect, Global Financial Journal, 6 (1), 1-7.

Lettau, M., and Ludvigson, S. (2002), Measuring and modeling variation in the risk return tradeoff, in Yacine Ait Sahalia, and Lars P. Hansen, ed.: Handbook of Financial Econometrics.

Litvinova, J. (2002), Volatility Asymmetry in High Frequency Data, working paper, Department of Economics, Duke University.

Love, R. and Payne, R. (2002), Macroeconomic news, order flows, and exchange rates, Typescript, London School of Economics, December.

Low, A. and Muthuswamy J. (1995), Information Flows in High Frequency Exchange Rates, Working paper, National University of Singapore.

Lu, X. and Wu, Y. (2006), Financial Market Reactions to Monetary Policy and Open Market Operations: The Australian Case, The Business Review, Cambridge, 174.

Lundblad, C. (2004), Risk, Return, and Asymmetric Volatility in the Long Run: 1836-2002, working paper, Department of Finance, Indiana University.

Lyons, R. K. (1988), Tests of the FX risk premium using the expected second moments implied by option pricing, Journal of International Money and Finance 7 (1), 91–108.

Lyons (1995), Tests of microstructural hypotheses in the FX market, Journal of Financial Economics, 39, 321–351.

Lyons (1997), A simultaneous trade model of the FX hot potato, Journal of International Economics, 45, 181–211.

Lyons (2001), The Microstructure Approach to Exchange Rates, MIT Press.

Lyroudi, K., Subeniotis, D. and Komisopoulos G. (2002), Market Anomalies in the A.S.E.: The Day of the Week Effect, Presentation at the 2002 European Finance Management Association, Annual Conference, London, UK.

Maberly, E. D. and Maris, B. A. (1991), The January Effect, Arbitrage Opportunities, and Derivative Securities: Has Anything Changed?, The Journal of Futures Markets, 11, 253–257.

Madura, J. and Tucker, A. (1992), Trade deficit surprises and the ex ante volatility of foreign exchange rates, Journal of International Money and Finance, 11, 492 – 501.

Marc R. (1983), The Anomalous Stock Market Behavior of Small Firms in January: Empirical Tests for Tax-Loss Effects, Journal of Financial Economics, 12, 1983, 89-104.

Mark, N. C. (1995), Exchange Rates and Fundamentals: Evidence on Long-Horizon Predictability, American Economic Review, 85, 201-218.

Mark, N. C. and Sul, D. (1998), Nominal Exchange Rates and Monetary Fundamentals: Evidence From a Small Post-Bretton-Woods Panel, Manuscript, Ohio State University.

Martens M. and Zein, J. (2002) Predicting financial volatility: high-frequency time series forecasts vis-à-vis implied volatility, Working paper, Erasmus University.

Malz, A. M. (2000), Do Implied Volatilities Provide Early Warning of Market Stress?, The Risk Metric Group, Working Paper 00-01.

Manaster, S. and Rendleman, R., (1982), Option Prices as Predictors of Equilibrium Stock Prices, Journal of Finance, 37, 1043-1058.

Martikainen T., Perttunen J., and Puttonen V. (1995), Finnish Turn of the Month Effects: Returns, Volume and Implied Volatility, The Journal of Futures Markets , 15 (6), 605.

Masson, P. R. and Turtelboom, B. G., (1997), Characteristics of the Euro, the Demand for Reserves, and Policy Coordination Under EMU, International Monetary Fund Working Paper, WP/97/58.

Mayhew, S. (1995), Implied volatility. Financial Analysts Journal, 51, 8 – 20

McEwan Ron (2002), The weekend effect in FOREX, Futures, 31, 22.

McFarland, J. W., Richardson R. P. and Sung, S. K. (1982), The distribution of foreign exchange price changes: Trading day effects and risk measurement, Journal of Finance 37, 693-715; the reply by the same authors to J.C. So, 1987, Journal of Finance 42, 189-194.

McGroarty F., Gwilym, O. and Thomas, S. (2005), Private information, excessive volatility and intraday empirical regularities in the spot foreign exchange market, Centre for Risk Research Working Papers, School of Management Paper No. CRR-05-01

McQueen, G. and Roley, V. R. (1993), Stock Prices, News, and Business Conditions, The Review of Financial Studies, 6 (3), 683-707.

Meese, R. A. and Rogoff, K. (1983), Empirical Exchange Rate Models of the Seventies: Do They Fit Our Sample?, Journal of International Economics, February 1983, 14, 3-24

Melvin M. and Yin, X. (2000), Public Information Arrivals, Exchange Rate Volatility, and Quote Frequency, The Economic Journal, 110, 644-661.

Merton, R. C. (1973), The theory of rational option pricing, Bell Journal of Economics and Management 314 Science, 4, 141–183.

Merton, R. C. (1973), An inter-temporal capital asset pricing model, Econometrica 42, 867–887.

Merton, R. C. (1980), On estimating the expected return on the market: an exploratory investigation, Journal of Financial Economics, 8, 323–361.

Merrill, A. (1966), Behavior of Prices on Wall Street. The Analysis Press, Chappaqua, NY.

Miller, E. (1988), Why a Day of the Week Effect, Journal of Portfolio Management 4, 43-48.

Mills, T. C., and Coutts, J. A. (1995), Calendar effects in the London Stock Exchange FTSE indices, The European Journal of Finance 1 (1), 79-93.

Mitchell, M. L. and Mulherin, J. H., (1994), The impact of public information on the stock market. Journal of Finance, 49, 923–950.

Morgenegg (1990), Statistical Study of Foreign Exchange Rates, Empirical Evidence of a Price Change Scaling Law, and Intraday Analysis, Journal of Banking and Finance, 14, 1189–1208.

Mundell, R. A. (1998), What the Euro Means for the Dollar and the International Monetary System, Atlantic Economic Journal, 26, 227-237.

Mussa, M. (2000), The Relationship Between the Euro and the Dollar, Journal of Policy Modeling, 22, 369-377.

Natividad, F. and Stone, J. (1990) A general equilibrium model of exchange market intervention with variable sterilization, Journal of International Money and Finance, 29, 133-145.

Neely, C. J. (2000), The Practice of Central Bank Intervention: Looking Under the Hood, Federal Reserve Bank Working Paper no. 2000-028.

Neely, C. J. (2005), An analysis of recent studies of the effect of foreign exchange Intervention, Federal Reserve Bank of Saint Louis, Working Paper no. 2005-03B.

Neely, C. J. (2005), Identifying the Effect of US Interventions on the Level of Exchange Rates, Federal Reserve Bank of Saint Louis, Working Paper no. 2005-031B.

Nelson, D. (1991), Conditional heteroscedasticity in asset returns: A new approach, Econometrica, 59, 349 – 370.

Newey, W. K., and West, K. D. (1987), A simple, positive semi-definite, heteroscedasticity consistent covariance matrix, Econometrica 55, 703-108.

Nikkinen J. and Sahlstrom, P. (2004), Impact of the federal open market committee's meetings and scheduled macroeconomic news on stock market uncertainty. International Review of Financial Analysis, 13 (1), 1-12.

Nikkinen J. and Sahlstrom, P. (2004), Scheduled domestic and US macroeconomic news and stock valuation in Europe, Journal of Multinational Financial Management., 14 (3), 201 -215.

Nikou, K. (1997) Market Results and the Phenomenon of the Weekend Effect on the Stock Market Returns, Master Thesis, University of Macedonia.

Neely, C. J. (1998). Technical analysis and the profitability of US FX intervention, Federal Reserve Bank of St. Louis, July/August (1984).

Neumann, M. J. (1983), Intervention in the mark/dollar market: the authorities reaction function, Journal of International Money and Finance, 3, 223-239.

Obstfeld, M. (1998), EMU: Ready or Not?, NEBR Working Paper Series, Working Paper No. 6682.

Officer, R. R. (1975), Seasonality in Australian capital markets: Market efficiency and empirical issues, Journal of Financial Economics 2, 29-51.

Ogden, J. P. (1990), Turn-of-the-Month Evaluations of Liquid Profits and Stock Returns: A Common Explanation for the Monthly and January Effects, The Journal of Finance, 45, 1259–1272.

O'Hara (1995), Market Microstructure Theory. Basic Blackwell, Basic Blackwell.

Olivier, J. and Rose, A. K. (1999), Noise Trading and Exchange Rate Regimes, NBER Working Paper Series, No. 7104.

Ozmen, T. (1997), Dunya Borsalarinda Gozlemlenen Anomaliler ve IMKB Uzerine Bir Deneme, Publication of the Capital Market Board of Turkey, No: 61.

Pagan and Hong (1991), Nonparametric Estimation and the Risk Premium, Cambridge, UK: Cambridge University Press, 51-75.

Pandey I.M. (2003), Is there seasonality in the SENSEX monthly returns?, Indian Institute of Ahmedabad, Vastrapur, Ahmedabad 380015 India.

Patell J. and Wolfson, M. (1979), Anticipated Information Releases Reflected in Call Option Prices, Journal of Accounting and Economics, 1, 117-140.

Pattell, J. M. and Wolfson, M. A. (1981), The ex ante and ex post price effects of quarterly earnings announcements reflected in option and stock prices, Journal of Accounting Research, 19, 434-457.

Patell J. M. and Wolfson, M. (1982), Good news, bad news, and the interday timing of corporate disclosures, Accounting Review, 57, 509–527.

Payne, R. (1996), Announcement Effects and Seasonality in the Intraday FX Market., Working paper, London School of Economics.

Pearce, D.K., and Roley, V.V. (1985), Stock prices and Economic News, Journal of Business, 58, 49-67.

Pearce, D. (1996), The robustness of calendar anomalies in daily stock returns, Journal of Economics and Finance, 20, 69-80.

Penman S. H. (1987), The Distribution of Earnings News Over Time and Seasonalities in Aggregate Stock Returns, Journal of Financial Economics 24, 193-214.

Perraudin, W. and Vitale, P. (1995), Inter-dealer trade and information flows in a decentralized foreign exchange market. In: Frankel, J.A., Galli, G., Giovannini, A. (Eds.), The Microstructure of Foreign Exchange Markets. The University of Chicago Press, Illinois

Pettengill, G and Jordon, B. (1988), A Comprehensive Examination of Volume Effects and Seasonality in Daily Security Returns, Journal of Financial Research, 11(1), 57-70.

Pettengill, G. N. (1989), Holiday closings and security returns. Journal of Financial Research, 12 (1), 57-67.

Phillips-Patrick, F. J. and Schneeweis, T. (1988), The 'Weekend Effect' for Stock Indexes and Stock Index Futures: Dividend and Interest Rate Effects. Journal of Futures Markets, 8 (1), 115-121.

Pohlmeier, W. (2005), Analyzing the Impact of News Announcements on Prices in the FX Market: A Conditional Volatility Consideration, Working paper, University of Konstanz.

Pong S., Shackleton, M. B., Taylor, S. J. and Xu, X. (2002), Forecasting Sterling/Dollar volatility: A comparison of implied volatilities and AR(FI)MA models, Working paper, Lancaster University.

Poon, S. H. and Granger, C. (2003), Forecasting Volatility in Financial Markets: Journal of Economic Literature, 41 (2), 478-539.

Portes, R. and Rey, H. (1998), The Emergence of the Euro as an International Currency, Economic Policy, 26, 307-322.

Poterba, C., and Summers, L. H. (1989), What moves the stock prices?, Journal of Portfolio Management, 15, 4-12.

Philip, P. (1982), Day of the week effects: Hourly data, University of Chicago, Chicago, IL, Manuscript.

Ramaswamy K. and MacKinlay, A. C (1988), Index-futures arbitrage and the Behavior of stock index futures prices, Review of Financial Studies, 1, 137-158.

Ramchander S. and Raymond S. (2002), The impact of federal reserve intervention on exchange rate volatility: evidence from the futures markets, Applied Financial Economics, 12, 231-240

Ravn, M. O. and Sola, M. (1996), A reconsideration of the empirical evidence on the asymmetric effects of money supply shocks: Positive versus negative and big versus small, Working Paper No. 1996-4, Department of Economics, Aarhus University, Denmark.

Reinganum, M. R. (1983), The Anomalous Stock Market Behavior of Small Firms in January: Empirical Tests for Tax-Loss Effects, Journal of Financial Economics, 12, 89-104.

Reinganum, M. R. and Shapiro, A. (1987), Taxes and stock return seasonality: evidence from the London Stock Exchange, Journal of Business, 60, 281–295 Reinganum.

Remolona, E. M., Dziwura, J. and Pedraza, I. (1995), The short end of the forward curve and asymmetric cat's tail convergence, Research Paper No. 9523, Federal Reserve Bank of New York.

Richards, P. H. (1979), U.K. and European share price behavior: The evidence (Kogan Page, London, and Nichols, New York).

Riepe, M. (1998), Is Publicity Killing the January Effect? Journal of Financial Planning, 11 (1), 64-70.

Ritter J. R. (1988), The Buying and Selling of Individual at the Turn of the Year, The Journal of Finance, 43, 701–717.

Ritter J. R. and Chopra, N. (1989), Portfolio Rebalancing and the Turn of the Year Effect, The Journal of Financed, 149–166.

Rogalski, R. J. (1984), New Findings Regarding day-of-the-week Returns Over Trading and Non-trading Periods: A note, Journal of Finance, 35, 1603–1614.

Rogalski, R., and S. Tinic (1986), The January Size Effect: Anomaly or Risk Mismeasurement, Financial Analysts Journal, November-December, 63-70.

Rogalski, R. and Maloney, S. (1989), Call-Option Pricing and the Turn of the Year, Journal of Business, 62, 539-552.

Roley, V. (1983), The Response of Short-Term Interest Rates to Weekly Money Announcements, Journal of Money, Credit and Banking, August, 15: 3444354.

Roll, R. (1983), Vas ist das? The turn of the year effect and the return premium of small firms, Journal of Portfolio Management, 18-28.

Romer, D. (1993), Rational asset-pricing movements without news, American Economic Review, 83, 1112–1130.

Ross, S. A., (1986), Regression to the Max, unpublished manuscript, Yale School of Management.

Rozeff, M. and Kinney, W. R. (1976), Capital market seasonality: The case of stock returns. Journal of Financial Economics, 3, 379–402.

Ryan, A. T. and White, H. (1998), Dangers of Data Driven Inference: The Case of Calendar Effects in Stock Returns, Discussion paper, 98-16.

Sager, M. J. and Taylor, M. P. (2004), The impact of European Central Bank Governing Council announcements on the foreign exchange market: a microstructural analysis, Journal of International Money and Finance, 23, 1043 – 1051.

Santemases, M. (1986), An Investigation of the Spanish Stock Market Seasonalities, Journal of Business, Finance and Accounting, 13 (2), 267- 276.

Schultz, P. (1985), Personal Income Taxes and the January Effect: Small Firm Stock Returns Before the War Revenue Act of 1917: A Note, Journal of Finance, 40, 333-343.

Schwert, G. W. (1981), The Adjustment of Stock Prices to Information about Inflation, Journal of Finance, 36, 15-29.

Schwert G. W., French K., and Stambaugh R. F. (1987), Expected stock returns and volatility, Journal of Financial Economics, 19, 3-30.

Schwert, G. W. (1989), Why Does Stock Market Volatility Change Over Time?, Journal of Finance, 44.

Scott, L. O. (1987), Option Pricing when the Variance Changes Randomly: Theory, estimation and an Application, Journal of Financial and Quantitative Analysis, 22 (4), 419-438.

Scott E. (1987), A study of diffusion processes for FX rates, Journal of International Money and Finance, 6, 465–478.

Scott E. and Tucker A. L. (1989), Predicting currency return volatility, Journal of Banking and Finance, 13 (6), 839-851.

Seha M. T. and Richard R. W. (1984), Risk and Return: January versus the Rest of the Year, Journal of Financial Economics, 13, 561–574.

Seyyed, F. J., Abraham, A., and Mohsen, A. (2005), Seasonality in stock returns and volatility: The Ramadan Effect, Research in International Business and Finance, 19, 374 – 383.

Shiyun, W. and Guan, L. (1999), A New Methodology for Studying Intraday Dynamics of Nikkei Index futures using Markov chains, Journal of Financial Markets, Institutions and Money, 9 (3), 247 – 265.

Silber, W. (1984), Market maker behavior in an auction market: an analysis of scalpers in futures markets, Journal of Finance, 39, 937-953.

Simpson, M. W., Ramchander, A. and Mukesh, C. (2005), The impact of macroeconomic surprises on spot and forward foreign exchange markets, Journal of International Money and Finance, 24, 693-718.

Simon, D. P. (1997), Implied Volatility Asymmetries in Treasury Bond Futures Options, Journal of Futures Markets 17 (8), 873 – 885.

Smirlock, M. and Starks, L. (1986), Day - of- the- Week and Intraday Effects in Stock Returns, Journal of Financial Economics, 197- 210.

So, J. (1987), The distribution of foreign exchange price changes: trading day effects and risk measurement: a comments, Journal of Finance 42, 181–188.

Solnik B. (1990) The Distribution of Daily Stock Returns and Settlement Procedures: The Paris Bourse, Journal of Finance, 45 (2), 1601-1609.

Solnik, B. and Bousquet, L. (1990), Day - of- the- Week Effect on the Paris Bourse, Journal of Banking and Finance, 14, 461- 468.

Solnik B., Boucrelle C. and Le Fur Y. (1996), International market correlation and volatility, Financial Analyst Journal, 52, 17-34.

Smidt, S. and Stewart, S. D. (1984), Risk Premium Seasonality, Working Paper, School of Management, Cornell University.

Spindt P.A., and Hoffmeister, J. R. (1988), The Micromechanics of the Federal Funds Market: Implications for Day-of-the-Week Effects in Funds Rate Variability, Journal of Financial and Quantitative Analysis, 23 (4), 401–416.

Steeley James M. (2001), A note on information seasonality and the disappearance of the weekend effect in the UK stock market, Journal of Banking & Finance, 25 (10), 1941-1956.

Stein Jeremy (1989), Overreactions in the options market, Journal of Finance, 44, 1011-1023.

Stephan, J. and Whaley, R. (1990), Intraday Price Changes and Trading Volume Relations in the Stock and Stock Option Markets, Journal of Finance, 45, 191-220.

Stewart, S. D. (1987), Bias In Performance Measurement During Contributions: A Note, The Financial Review, 22, 339-343.

Stigum, M. (1983), The Money Market, Dow-Jones Irwin, Homewood, IL (1983).

Stock, H. J. and Watson, M. W. (2003), Has the Business Cycle Changed? Evidence and Explanations, Federal Reserve Bank of Kansas City Symposium on Monetary Policy and Uncertainty: Adapting to a Changing Economy.

Stulz R. M, Chan, K. C., Christie, C. and Paul, H. (1995), Market structure and the intraday pattern of bid-ask spreads for NASDAQ securities, Journal of Bossiness, Chicago, 68, 1-35.

Sullivan S. A. and Ord, J. K. (1987), Kendall's Advanced Theory of Statistics, New York: Oxford University Press.

Sun P. and Sutcliffe C. (2001), Scheduled Announcements and Volatility Patterns: The Effects of Monetary Policy Committee Announcements on LIBOR and Short Sterling Futures and Options, Journal of Futures Markets, 23 (8), 773 – 797.

Sundkvist, K. and Vickstrom, M. (2000), The Day of the Week Effect and Option Pricing – A Study of the German Option Market, Working paper, Swedish School of Economics and Business Administration.

Sundkvist, K. and Vickstrom, M. (2000), Intraday and Weekend Volatility Patterns – Implications for Option Pricing, Working paper, Swedish School of Economics and Business Administration.

Szakmary A., Ors, E., Kim, J.K. and Davidson III, W.D. (2002), The predictive power of implied volatility: Evidence from 35 futures markets, Working paper, Southern Illinois University.

Tabak, B. M. (2006), The Dynamic Relationship between Stock Prices and Exchange Rates: Evidence from Brazil, Working paper, Banco Central Do Brasil.

Tan, R. S. K. and Tat, W. N. (1998), The diminishing calendar anomalies in the stock exchange of Singapore, Journal of Applied Financial Economics, 8 (2), 119-125.

Tang, G. Y. N. and Kwok, K. (1997) Day of the Week Effect in International Portfolio Diversification: January vs Non-January, Japan World Economics, 9, 335-352.

Tanizaki, H. (2004), On Assymetry, Holiday and Day of the Week Effects in Volatility of Daily Stock Returns: The Case of Japan, Journal of Japan Statistics, Volume 34 (2), 129-152.

Tastan, H. (2005), Estimating time-varying conditional correlations between stock and foreign exchange markets, Department of Economics, Yildiz Technical University, Yildiz Kampusu, Besiktas Istanbul, Turkey.

Tauchen, G. (2005), Stochastic Volatility in General Equilibrium, Working paper, Department of Economics, Duke University.

Taylor, S. J. (1986), Modeling Financial Time Series, John Wiley, Chichester.

Taylor, S. J. (1987), Forecasting the Volatility of Currency Exchange Rates, International Journal of Forecasting, 3, 159-170

Thaler R. (1987), Seasonal movements in security prices: Weekend, holiday, turn of the month and intraday effects, Journal of Economic Perspectives1, 169–177.

Theobald, M. and Price, V. (1984) Seasonality Estimation in Thin Markets, Journal of Finance, 39, 377- 392.

Theodossiou P. and Lee U. (1995), Relation Between Volatility and Expected Returns Across International Stock Markets, Journal of Business Finance and Accounting, 22(2), 289-300.

Tinic, S. and Barone-Adesi, G. (1983), Seasonality in stock prices: A test of the 'tax-loss selling' hypothesis, Unpublished manuscript (Faculty of Business, University of Alberta, Edmonton).

Torous, W., Valkanov, R. and Yan, S. (2003), On Predicting Stock Returns with Nearly Integrated Explanatory Variables, Journal of Business, 77 (4), 937-966.

Tucker, A. L. and Scott, E. (1987), A study of diffusion processes for FX rates, Journal of International Money and Finance, 6, 465–478.

Tuner, C. M., Startz, R. and Nelson, C. R. (1989), A Markov model of heteroscedasticity, risk, and learning in the stock market, Journal of Financial Economics, 25, 3-22.

Urich, T. and Wachtel, P. (1981), Market response to the weekly money supply announcements in the 1970s, Journal of Finance 36, 1063-1072.

Van der Sar, N. L. (2003), Calendar Effects on the Amsterdam Stock Exchange (2003), De Economist, 151, 3, 271.

Veronesi, P. (1999), Stock Market Overreaction to Bad News in Good Times: A Rational Expectations Equilibrium Model, Review of Financial Studies, 12, 975-1007.

Vetter, D. E. and Wingender, J. R. (1996), The January effect in preferred stock investments, Quantitative Journal of Business Economics, 35, 79–88.

Wachtel P. and Urich, T. (1984), The Effects of Inflation and Money Supply Announcements on Interest Rates, Journal of Finance, 39, 1177-1188.

Walsh C. (1984), Interest Rate Volatility and Monetary Policy, Journal of Money, Credit and Banking, 16, 133-150.

Wasserfallen W. and Zimmermann, H. (1985), The Behavior of Intra-Daily Exchange Rates, Journal of Banking and Finance, 9, 55-72.

Watanabe, T. (1999), A non-linear filtering approach to stochastic volatility models with an application to daily stock returns, Journal of Applied Econometrics, 14, 101-121.

Watanabe, T. (2000), Bayesian Analysis of dynamic mixture models: Can They Explain the Behavior of Returns and Trading Volume?, Journal of Business and Economic Statistic, 18, 199-210.

Wei S. J. and Frankel, J. A. (1991), Are option-implied forecasts of exchange rate volatility excessively variable?, NBER working paper No.3910.

Wei, P. and Zee, S. (1998), Interday variation in price volatility, volume and open interest in the market for foreign currency futures. Journal of Research in Finance, 1, 6–27.

Werner, I. M. and Kleidon, A. W., (1996), UK and US trading of British cross-listed stocks: An intraday analysis of market integration, Review of Financial Studies, 9, 619–664.

Westerfield, (1977), An examination of foreign exchange risk under fixed and floating rate regimes, Journal of International Economics, 7, 181–200.

Whaley, R.E. (2000), The investor fear gauge, Journal of Portfolio Management, 26, 12–17.

Whitelaw, Robert F. (1994), Time Variations and Covariations in the Expectation and Volatility of Stock Market Returns, Journal of Finance, 49, 515 – 541.

Wiggins, J. B. (1987), Option Values under Stochastic Volatility: Theory and Empirical Estimates, Journal of Financial Economics 19 (2), 351 – 372.

Williams, J. and Angel, L. (2006), Implications of news asymmetries in foreign exchange, European Financial Management Conference, Apr 20-22.

Wilson, J. W. and Jones, C. P. (1993), Comparison of seasonal anomalies across major equity markets: a note, Financial Review, 28 (1), 107-115.

Wong, P. L., Neoh, S. K. Lee, K. H. and Thong, T. S. (1990), Seasonality in the Malaysian stock market, Asia Pacific Journal of Management, 7, 43-62.

Wong, K. (1995), Is There an Inter-month Effect on Stock Returns in Developing Stock Markets? Applied Financial Economics, 5 (5), 285-289.

Wood, R. A., McInish, T. H. and Ord, J. K. (1985), An investigation of transaction data for NYSE stocks, Journal of Finance, 40, 723–741.

Wood, B. G. Jr. (1994), International Review of Financial Analysis Seasonalities and the 1987 crash: The international evidence, 3(1), 65-91.

Wu, G. (2001), The Determinats of Asymmetric Volatility, Review of Financial Studies, 14 (3).

Xinzhong, X. and Taylor, S. (1994), The Term Structure of Volatility Implied by FX Options, Journal of Financial and Quantitative Analysis, 29 (1).

Yadav, P. K. and Pope, P. F. (1990), Stock index futures pricing: International evidence, Journal of Futures Markets, 10, 573-603.

Yalcin, Y. and Yucel, E. M. (2006), The Day of the Week Effect on Stock Market Volatility: Evidence from Emerging Markets, Finance University of. Dobris, 56 (5,6), 258.

Yamori, N. and Mourdoukoutas, P. (2003), Does the Day-of-the-week Effect in Foreign Exchange Currency Markets Disappear? Evidence from the Yen/Dollar Market, International Finance Review, 4, 443-459.

Yamori, N. and Kurihara, Y. (2004), The day-of-the-week effect in foreign exchange markets: multi-currency evidence, Research in International Business and Finance, 18, 51-57.

Zehr, L. (1989), Quarter's end recovery just a house of cards, Globe and Mail, B2.

Ziemba, W. T. (1991), Japanese security market regularities: Monthly, turn of the month and year, holiday and golden week effects. Japan and the World Economy, 3 (2), 119-146.

Ziemba, W.T. (1994), World Wide Security Market Regularities, European Journal of Operation Research, 74, 198 – 229.