Essays in International Trade

by

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PhD Dissertation

at the

University of Strathclyde

May 19, 2010

Declaration of Authenticity

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has lead to the award of a degree.

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Acknowledgments

The research in this thesis was supported by an Economic and Social Research Council (ESRC) Studentship and University of Strathclyde Departmental Stipend. The financial assistance of both organisations is gratefully acknowledged. In addition to my studies at the University of Strathclyde, this work has benefited from an internship at the World Trade Organization. I am indebted to both institutions for their support and the great intellectual atmosphere in which I could discuss my work. I would like to thank the participants at the research seminar at the University of Strathclyde, the ETSG conference in Warsaw and Rome, the Post Graduate Conference in Nottingham and the Mid-West trade meeting for their comments.

I would like to thank to thank my supervisor Prof Ian Wooton. The meetings with him were always a source of inspiration and without his patience, guidance and support this thesis could not been written. I am also grateful to a number of economists who I had the chance to discuss my work with. In particular I would like to thank Dr Catia Montagna, Dr Giuseppe De Feo and Dr Alex Dickson for their invaluable comments on my work. Thanks to Catherine Stevens for her patience in reading economics and her support throughout my PhD.

Finally, this thesis could not have been written without the support of both my parents - Eva Hoefele and Lutz Hoefele. You were a great help in my academic endeavor with your encouragement and endless support. I am also indebted to my family and friends for being a source of distraction and support whenever needed.

Abstract

This thesis comprises two topics. Firstly, I argue that Governments have an incentive to support their domestic firm that operate on an international market. I develop a model in which firms compete on an international market and can invest in differentiating their products. I show that the optimal policy - a tax or subsidy - depends on the strength of the market-expansion effect of product differentiation. Secondly, I argue that offshoring has a positive impact on an economy that offshores production stages. I further show that a country that receives the offshored production stages might not gain from offshoring because less factors are available for research.

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Chapter 1

Introduction

This thesis combines two branches of my research. The first part is on product differentiation and strategic trade policy. The second part is on growth and offshoring.

In the first part of the thesis, I analyse firms that operate in a single market and differentiate their products to attract consumers. For example, by changing the design or some aspects of their product, firms try to signal the uniqueness of their product to the consumer or to show that their product is better than their competitor's product. In Part One, I show that firms have an incentive to differentiate their product strategically. Governments can increase domestic welfare, because they can influence the strategic interaction of firms by announcing a subsidy or tax. This is the profit shifting motive of strategic trade policy, where one country can reap a larger share of the aggregate profits earned in the market. I show that the form of the policy depends on what I call the market-expansion effect.

In the second part of the thesis, I analyse offshoring of intermediate production stages is becoming increasingly important. In particular, the production of some intermediate inputs is not profitable in an economy and may therefore be moved to a lower cost location. The final assembly might still be located in the economy; however, the particular intermediate is now imported. The production facility is lost and with it the jobs. This particular feature of offshoring is what I am interested in. If the workers that were previously employed in those lost jobs are allocated to a sector that fosters the technological improvement of an economy, the economy might grow faster. In Part Two, I show that the reallocation of factors of production indeed accelerate growth. I further show that, even if only one factor of production is offshored, it has an knock-on effect on other factors of production so that the economy growth rate increases.

Part I

Strategic Policy in International Markets

Chapter 2

Strategic Trade Policy in International Trade

Two branches of literature are reviewed in this section. Firstly, I introduce and discuss utility functions of product differentiation. Secondly, I review the arguments for strategic policy intervention in international markets. The aim of this introductory chapter is to discuss concepts in the literature important in the next chapter. Wherever possible, I introduce the concepts in a very simple model. The literature review is far from exhaustive, but aimed to provide a foundation for the understanding of the following chapter.

2.1 Product Differentiation

From a firm's point of view, a higher degree of differentiation is desirable if less competitive pressure leads to higher profits. Therefore, it might be a viable strategy for firms to invest in differentiating themselves from the rest of their competitors. In a City of London (2006) survey of firms based in London, firms named strategies they used to differentiate themselves as important. For example firms, on average, ranked the offering of a unique product or service higher than having low costs or prices (see table 3.1 in chapter 3). This suggests that firms systematically think about differentiating their products.

Consumers' taste for differentiated products is a common assumption in international trade. Krugman (1980) and (1979) showed in a model of monopolistic competition, based on Dixit and Stiglitz (1977), that nations gain from trade in the presence of differentiated products because a larger variety is available to them. It is accordingly known as the "love-of-variety" approach. The preferences of consumers for more variety give rise to intra-industry trade. In contrast, Brander (1981) shows that even if goods are homogeneous, intra-industry trade arises in a model of imperfect competition. This is because monopoly rents in the respective foreign market provide firms with an incentive to export. Brander and Krugman (1983) add trade costs and a "segmented market" perception to Brander (1981). Due to the segmented market perception, firms are able to distinguish between the domestic market and the foreign market. These additional two assumptions result in "reciprocal dumping" - firms sell their goods at a lower price in the foreign market than at the domestic one. They therefore show that intra-industry trade arises despite trade distortions. By combining the love-of-variety approach with the one found in Brander (1981), Bernhofen (2001) shows that intra-industry trade increases in the degree of product differentiation. Consumers value variety, similar to Krugman (1980), and thus the volume of intra-industry trade increases the more the products differ. The reason is that the more the goods are differentiated, the closer the variety-specific demand curve is to the market demand curve, making it more viable for a firm to set a higher output.

The general literature on product differentiation distinguishes between two kinds of differentiation: vertical product differentiation and horizontal product differentiation. Philips and Thisse (1982) define the types of differentiation as follows. Products are vertically differentiated if they differ in their quality and can be ranked accordingly, where the best quality good is the most desired good. For example, the same notebook is often available with different processor speeds and consumers generally have a preference for the fastest one available. Products are horizontally differentiated if products differ in their versions. For example, a notebook is available in different colours. In that case, a consumer would buy the notebook with the colour closest to their own preference.

2.1.1 Representative Consumer and Product Differentiation

Horizontal product differentiation in this thesis is modelled in a representative consumer approach. It is assumed that all households share the same preferences, which can therefore be aggregated. The preferences are assumed to exhibit two desirable features. Firstly, the representative consumer values variety. Secondly, consumers perceive the goods as differentiated. In the following I choose the simplest case of two differentiated goods, $i = A, B$. Following Bowley (1924), a utility function that comprises both desired properties is

$$U = a(q_A + q_B) - b\left(\frac{q_A^2}{2} + \frac{q_B^2}{2}\right) - b\theta q_A q_B + m, \tag{2.1}$$

where a and b are parameters, and $\theta \in [0, 1]$ is the degree of product differentiation. For a high value of θ, A and B are close substitutes, with perfect substitutes if $\theta = 1$. The good m is a homogeneous good and chosen to be the numeraire. The utility function is quasilinear which implies that the demand for the differentiated goods is independent of the consumer's income.

The basic idea behind this formulation of horizontal product differentiation is as follows. The representative consumer values the consumption of two differentiated goods, which is expressed by the term $aq_i - (b/2)q_i^2$ for $i = A, B$. This term is concave which implies diminishing marginal utility from the consumption of the good. The term $b\theta q_A q_B$ implies that the consumer perceives the goods as differentiated. The more distinct the two goods become, the less dependent the consumption decision of the two goods is on one another. Due to the symmetry of the utility function, the consumer prefers a balanced consumption of both differentiated goods rather than consuming one differentiated good more than the other. The result of these assumptions on the utility function is that the more different the products are perceived to be, the higher the utility received from consuming each good is. In that sense, the consumer prefers extremes to similar products. For example, assume the two goods are ice cream which is available in two flavours only - dark chocolate and milk chocolate - which are very similar to one another. Then assume that instead of dark chocolate the other flavour is vanilla, which is markedly different to milk chocolate. Additionally, the consumer cares about the mix of ice cream. If the flavours are more distinct, a consumer might get a higher marginal utility from consuming milk chocolate ice-cream.

The implication of this formulation of utility for the two producers of the goods is as follows. Each producer faces its respective inverse demand curve $p_i = a - bq_i - b\theta q_j$ for $i = A, B$ and $j \neq i$. With a higher degree of product differentiation (i.e. θ closer to 0), the strategic term $b\theta q_j$ diminishes. Bernhofen (2001) calls this the term of (import) competition. The more substitutable the products are, the stronger is the impact of the rival's behaviour on a firm's one strategy. In other words, a higher degree of product differentiation reduces the competition between the firms.

Product Differentiation with Market Expansion

In the utility function 2.1, the market expands with product differentiation. The market expansion effect of product differentiation is defined as a shift in the demand curve. The intuition is that consumers receive a higher marginal utility from consuming each good and thus their willingness to spend on the overall market increases as well. To see the market expansion effect, I rewrite the inverse demand function to derive its direct form, which yields

$$q_i = \frac{a}{b(1+\theta)} + \frac{\theta p_j - p_i}{b(1-\theta^2)} \quad i = A, B. \tag{2.2}$$

Inspecting the first term on the right hand side shows that the maximum quantity sold in market i increases in the degree of product differentiation and thus the market expands.

Product Differentiation without Market Expansion

Shubik and Levitan (1980) produce a different utility function exhibiting the desired properties. The idea is that the market does not expand with more product differentiation. Although the third term vanishes with more differentiated products, the consumer puts more emphasis on the diminishing marginal utility in the second term. In that respect, more product differentiation disentangles the market. An example for this utility function is

$$U = a(q_A + q_B) - b(2-\theta)\left(\frac{q_A^2}{2} + \frac{q_B^2}{2}\right) - b\theta q_A q_B + m \tag{2.3}$$

To see the property of no market expansion, I write the demand function in its direct form

$$q_i = \frac{a}{2b} - \frac{(2-\theta)p_i + \theta p_j}{4b(1-\theta)} \quad i = A, B. \tag{2.4}$$

Thus the market does not expand in the degree of product differentiation as the intercept a is independent of θ. Therefore, changes in the degree of product differentiation only change the slope.

2.2 Strategic Trade Policy

In this section, I review the arguments of strategic trade policy. Before doing so, I review the dynamic game introduced by Stackelberg to highlight the first-mover advantage. Assume a duopoly, where one firm (the leader) moves first and the second firm (the follower) observes the strategy of the leader and then sets its own strategy. In the case of quantity-setting behaviour, it is straightforward to show that the leader sets a higher output - the monopoly output - and receives a higher profit compared to a simultaneous move game. The follower, setting a lower output, receives a lower profit compared to the static game. In other words, there is a first-mover advantage in the game. In the case of price setting behaviour, the result can be expanded; however, it has important differences. The leader can achieve a higher profit by setting a higher price, but the follower reacts by setting a lower price. With a lower price, the follower gets a larger share of the market and achieves relatively higher profits. In that sense there is a relative first-mover disadvantage, although both firms obtain higher profits. The reason for the difference between the simultaneous-move game and two-stage game is that the leader can, by assumption, credibly commit to a strategy of higher output or price. In the simultaneous-move game, announcing a higher output is an empty threat as the rival knows that it does not correspond to an equilibrium behavior. Being the leader in the game enables the firm to make the threat credible, forcing the follower to adapt to the situation.

The argument of the literature on strategic trade policy is based on the assumption that a government could intervene and make the firm's threat credible by behaving like a Stackelberg leader towards the firm. The incentive for a government to intervene is to increase the profits of its domestic firm. In the following section, I review the main arguments of the literature on strategic trade policy. I introduce a simple version of market rivalry using a linear demand function. The review is aimed towards introducing the main arguments needed in this part of the thesis and thus is selective in the parts of the literature discussed. I rewrite the models using the utility function in (2.1) and demand functions derived from it.

Strategic complements and strategic substitutes are also important concepts used in this part of the thesis. In Bulow, Geanakoplos, and Klemperer (1985), strategies are defined as strategic complements if the marginal profits of a firm increase in response to a change in the rival's strategy. Let two firms A and B compete for the same market by setting strategies S_A and S_B respectively. Then the strategies are complements if

$$\frac{\partial^2 \pi_A}{\partial S_A \partial S_B} > 0. \tag{2.5}$$

The strategies are strategic substitutes if the marginal profit of one firm decreases in a change in the rival's strategy. Formally, this implies that

$$\frac{\partial^2 \pi_A}{\partial S_A \partial S_B} < 0. \tag{2.6}$$

The sign of the cross derivative determines the response of a firm to its rival's behaviour. For example, assume that firm B chooses to play a more aggressive strategy - an increase in output or a decrease in price. Depending on how firm A's marginal profit changes in response, A will choose its response to the more aggressive strategy. If the marginal profits fall, it will want to play a less aggressive strategy, while, if the marginal profits increase, it will want to adopt a more aggressive strategy.

2.2.1 Export Rivalry

Quantity Competition

Brander and Spencer (1985) show that if firms are competing over quantities, an export subsidy is the optimal trade policy. I will demonstrate the main points of the paper below, deviating from the original set-up to enhance comparability throughout the section without loss of generality. The set up of the model is as follows. There are two countries $i = A, B$ which each host one firm. These firms compete for a third market by setting quantities q_i. The governments are able to announce per-unit export subsidies s_i. The timing of the games is that governments announce the subsidies in the first stage and firms set quantities in the second stage. In each subgame, players move simultaneously and the move of each player becomes common knowledge once the players have moved. The whole game is solved backwards. The demand function is derived from the utility function 2.1, where I, for simplicity, assumed $a = b = 1$. The demand functions therefore take the functional form[1]

$$p_i = 1 - q_i - \theta q_j. \tag{2.7}$$

With this formulation, the market size is increasing with the degree of product differentiation. The marginal costs are assumed to be zero. The profit function of a firm is

$$\pi_i(q_A, q_B; s_i) = [p(q_A, q_B) + s_i]q_i \quad i = A, B. \tag{2.8}$$

[1] Brander and Spencer (1985) assume the same structure of the game; however, the demand system is more general.

The subsidy increases the per-unit revenues of a firm[2]. The first order condition provides the quantity reaction function

$$q_i(q_j) = \frac{(1+s_i)}{2} - \frac{\theta}{2} q_j \quad i = A, B \tag{2.9}$$

The second order condition that the profit function is concave is satisfied. Additionally, the cross derivative satisfies $\partial^2 \pi_i \,/\, \partial q_j \partial q_i = -\theta < 0$ for $i = A, B$. This implies that the reaction functions are downward sloping. A higher output by one firm implies a fall in the market price and thus lower revenue for its rival. The latter responds by setting a lower output until marginal revenue equals to marginal costs.

Both reaction functions are depicted in figure 2.1. The solid lines represents the reaction functions of the firms, where I assume no subsidy for simplicity[3]. The reaction functions are the optimal responses to the rival's output choice. The iso-profit curves are denoted by π_i, with $\pi'_A > \pi_A$. The equilibrium in the quantity game is found at the intersection of both reaction functions. Firm i's optimal output is $q_i^* = 1\,/(2+\theta) + (2s_i - \theta s_j)\,/\,(4-\theta^2)$ for $i = A, B$. The outputs are the equilibrium behaviour and neither firm has an incentive to deviate; if a firm announces it will set a higher output, then the other firm knows that this is an empty threat. However, if the government in A announces a subsidy in the first stage, the situation changes. I depict the case of a subsidy in figure 2.1 by the dashed line. The subsidy causes the reaction function of firm A to shift out, making it optimal for firm A to set a higher output in response to any given output by firm B. The equilibrium output of the firm in A increases whereas the output of the firm B decreases. This is made possible because the government can make the threat of higher output credible by announcing the subsidy. To show that the output increases, I totally differentiate the first order conditions of

[2] In Brander and Spencer (1985), positive marginal costs are assumed which the subsidy reduces.

[3] Alternatively I could assume a positive subsidy and impose $s_A = s_B$ to achieve the symmetrical outcome.

both firms, which yields

$$\begin{aligned} \frac{dq_A}{ds_A} &= \frac{2}{(4-\theta^2)} \\ \frac{dq_B}{ds_A} &= -\frac{\theta}{(4-\theta^2)} \\ \frac{dq_A}{ds_A} + \frac{dq_B}{ds_A} &= \frac{1}{(2+\theta)}. \end{aligned} \tag{2.10}$$

Aggregate output increases in response to the subsidy, as seen in the third expression of (2.10).

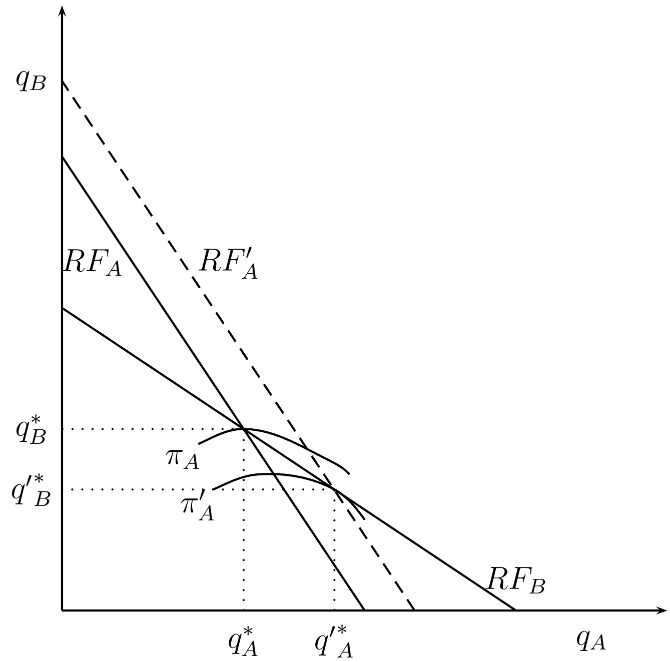

Figure 2.1: Cournot Reaction Functions

The sign of the subsidy must depend on its impact on welfare in the respective domestic economy. Welfare in country A is measured solely by its firm's profit less the costs of the subsidy payment, $W = \pi(s_A) - s_A q_A$. The reason is that the firm operates on a third market and thus has no impact on consumers in each country. Accordingly welfare is the pure profits of the firm. Maximizing welfare with respect to the subsidy yields

$$s_A = \frac{\theta^2(2-\theta)}{4(2-\theta^2)} \tag{2.11}$$

which is positive. Hence, a government has the incentive to offer unilaterally a subsidy to its exporting firm. The reason is that a subsidy shifts profits towards A. The subsidy leads firm A to increase its market share by expanding its own output at the expense of firm B's output. A larger output share implies a larger share of the market profits.[4] Brander and Spencer (1985) investigate the effect of an export subsidy on the terms of trade. With perfect competition an economy would be detrimentally affected by a subsidy because of a fall in the terms of trade. However, if one sector is characterized by a Cournot duopoly, a (small) subsidy improves welfare because of the profit shifting effect despite a fall in the terms of trade.

Price Competition

In Eaton and Grossman (1986), the case of Bertrand competition and government intervention is discussed. The previously made assumptions remain untouched except that firms now set prices instead of outputs. Governments decide whether to subsidize or tax their domestic exporting firm. I assume the same linear inverse demand function as above. The profit function can be written as $\pi_i(p_A, p_B, s_i) = [p_i + s_i]q_i(p_A, p_B)$ for all $i = A, B$. The reaction functions take the form

$$p_A(p_B) = \frac{(1-\theta) - s_A}{2} + \frac{\theta}{2} p_B \quad \forall i = A, B \tag{2.12}$$

The profit functions are concave. The cross derivative $\partial^2 \pi_i \,/\, \partial p_j \partial p_i > 0$, implies that prices are strategic complements; the marginal profit of a firm increases if the other firm increases its price. Given the assumption of Bertrand competition, a higher price set by the competitor eases the pressure for low prices of a firm.

Given the cross derivative and the condition for concave profits, the reaction functions are upward sloping. The reaction functions are depicted in figure 2.2. The solid lines represent the reaction function, assuming no government policy. Again, the optimal prices are found at the intersection of the reaction functions.

[4] Although the total output increases in the market, the profits increase as well.

The profits increase as the iso-profit lines move further away from the origin. If one firm announces a higher price than the equilibrium price, it is an empty threat as it is not in compliance with optimal behaviour. In order to increase domestic profits, a government has to influence the domestic firm to set a higher price. I assume that only country A is active in policy. The strategy chosen by the government is to announce a tax to shift the reaction function of firm A out, which can be seen by the dashed line. By making its domestic firm unable to commit to a lower price, the government increases domestic profits. By using the tools developed in the previous section, it can be shown that a government has the unilateral incentive to set an export tax.

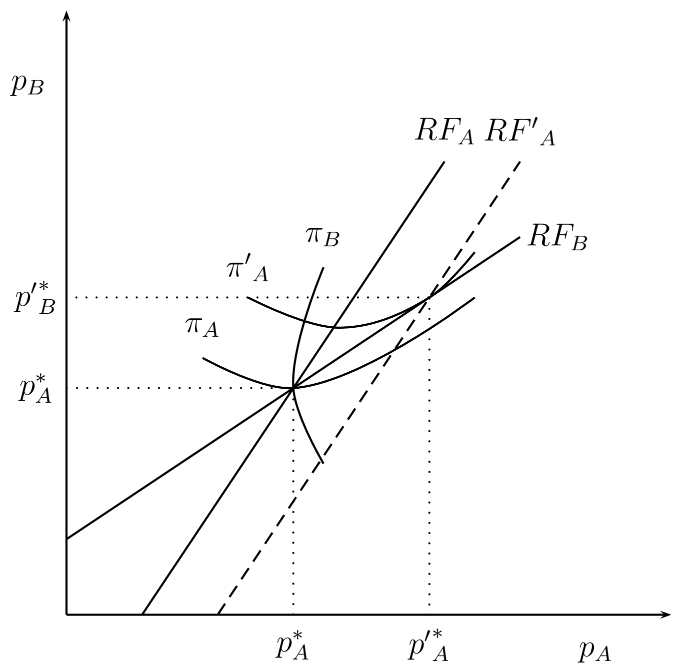

Figure 2.2: Bertrand Reaction Functions

An important contribution of the paper is to shed light on why these different results arise. The authors show that the difference in the firm's conjectures, the expected response of the rival, and the actual response of the rival[5], generate a

[5]See Theorem 1 in the paper.

subsidy in one case and a tax in the other. For instance, with both Cournot and Bertrand competition, firms maximize profits by taking the rival's strategy as given. However, a firm overestimates or underestimates the actual output response of the rival. The link between expected and actual response is as follows. In both cases of competition, a firm behaves as if the rival does not change its strategy in response to the firm's change in strategy. In the case of Cournot competition, the actual response to a higher output is a reduction of the rival's output because the outputs are strategic substitutes, and thus firms overestimate the response of their rival. In the case of Bertrand competition, the actual response to a reduction in the price is for the rival to reduce price as well, as prices are strategic complements. A reduction in prices implies an increase in output and thus firms underestimate the response of their rival. The link to the government policy is that a government has to take into account the actual response in order to set the optimal strategy. In the case of Cournot competition, a larger market share implies higher profits. By announcing a subsidy, firm A sets a higher output. Firm B, however, forfeits some of its market share because it is the disadvantaged firm. Therefore it has to give the domestic firm an incentive to set a higher output. It does so by announcing a subsidy that reduces the marginal cost of the domestic firm. In the case of Bertrand, a government sets a tax because a higher price set by its domestic firm implies a higher price set by the rival.

2.2.2 The Optimal Policy in a Cournot Setting

The question arises as to how the equilibrium subsidy is affected by both governments announcing subsidies, i.e. how governments behave in the Nash subsidy game. Let the welfare function be $W_i = \Pi_i(s_A, s_B) - s_i x_i$ for $i = A, B$, where $\Pi(s_A, s_B)$ is a firm's profit, including the subsidy payment. The first order conditions in the subsidy game imply

$$s_i = \frac{\theta^2(2-\theta)}{4(2-\theta^2)} - \frac{\theta^3}{4(2-\theta^2)} s_j \quad \forall i = A, B \tag{2.13}$$

The slope of the reaction function implies that the subsidies are strategic substitutes. The optimal subsidy is

$$s_A^* = s_B^* = \frac{\theta^2}{4(2-\theta^2)+\theta^3} \tag{2.14}$$

which is positive. Brander and Spencer (1985) obtain the same qualitative result of a subsidy.

2.2.3 The Optimal Policy in a Bertrand Setting

To complete the discussion on strategic trade policy, I discuss the optimal policy under Bertrand competition when both governments are active. I show that in this case an export tax is optimal. Let the welfare function be $W_i = (1 + s_i)p_i q_i(p_i, p_j) - c_i q_i - s_i q_i$ for $i = A, B$, where s_i is the policy instrument and $s_i < 0$ corresponds to a tax. To make matters simple, I assume that the goods are perfect substitutes, $\theta = 0$, and that costs are symmetric. The optimal policy is

$$s_A^* = s_B^* = c - 1 \tag{2.15}$$

where $t \in [-1, 0)$ which is the desired result.[6] Eaton and Grossman (1986) present more general conditions under which the result of a tax holds. In their Proposition 2 in the paper they state that the sign of the policy is equal to the sign of the cross-derivative of the profits with respect to the prices, $\partial\pi_i/(\partial p_j \partial p_i)$. The sign of the latter derivative is positive in the specific model presented here.

2.2.4 Investment Subsidies

In the previous section I showed how, in a simple model of export rivalry, the strategic nature influences the sign of the optimal policy. However, the case of export promotion is of less practical relevance as it is prohibited under WTO rules[7]. Another way to support domestic firms on international markets is to

[6]Recall that the marginal costs of the firms are non-negative and are below the choke price which is normalized to 1.

[7]However, there exist exceptions for this. See WTO (2004).

bolster the R&D of firms. This form of policy intervention has become important in the literature. In a seminal contribution by Brander and Spencer (1983), the possibility of supporting cost-reducing R&D is analyzed. The set-up used is similar to the one above, altered to study the impact of a R&D subsidy for a domestic firm. I briefly review their main arguments below in a simple model. In particular, I emphasize the reasons as to why a subsidy or tax is optimal: i) the strategic nature of the investments and ii) the friendliness of the investments. The former reason is familiar by now, whilst the latter reason refers to the effect of a firm's strategy on the profit of the competitor. Investments are unfriendly if the profit of a firm falls if the competitor plays a more aggressive strategy. The important difference between the concepts is that the strategic nature influences the marginal behaviour of a firm whereas the friendliness influences the absolute profits of a firm.

The set-up of the model is as follows. Two countries $i = A, B$ exist, each country hosting one firm. The firms compete for a third market. The demand curves are assumed to be linear and take the form $p_i = a - q_i - q_j$, where, for simplicity, goods are perfect substitutes (i.e. the degree of product differentiation is set to one).[8] Each firm has a marginal cost c which it can reduce by investing in R&D. These investments are denoted by x_i for $i = A, B$. The game has three stages. Firstly, the government announces a subsidy. Secondly, the firms choose their investments, taking the subsidy as given. Thirdly, firms compete for the market and set outputs. The game is solved backwards. For simplicity, I assume that only the government in A actively engages in policy. The second stage profit functions are

$$\begin{aligned} \pi_A &= \left(\tfrac{a-c+2x_A-x_B}{3}\right)^2 - \tfrac{1}{2}x_A^2 + s_A x_A \\ \pi_B &= \left(\tfrac{a-c+2x_B-x_A}{3}\right)^2 - \tfrac{1}{2}x_B^2, \end{aligned} \tag{2.16}$$

where $\frac{1}{2}x_i^2$ are convex investment costs. The subsidy is denoted by s_A and paid per unit of investment. The second stage of the games involves the firms choosing

[8] I do this without losing generality.

	Friendly Investment	Unfriendly Investment
Strategic Complements	Subsidy	Tax
Strategic Substitutes	Tax	Subsidy

Table 2.1: The Optimal Policy

their optimal investments. The investment reaction functions are

$$\begin{aligned} x_A &= 4(a - c - x_B) + 9s_A \\ x_A &= 4(a - c - x_A). \end{aligned} \tag{2.17}$$

The reaction functions are downward sloping. Hence, the best response of a firm to its rival's higher investment is to reduce its own investment. The cross derivative is $\partial^2\pi_i \,/\, \partial x_j \partial x_i = -\frac{4}{9} < 0$, which implies that cost-reducing investments are strategic substitutes.

In the first stage the government in A chooses the optimal subsidy by maximizing welfare, $W_A = \pi_A(x_A^*, x_B^*) - s_A x_A^*$. Note that the optimal investments are a function of the subsidy, $x_i^*(s_A)$. The first order condition of a welfare maximum is $\partial W_A \,/\, \partial s_A = 0$. The optimal subsidy is[9]

$$s_A = \frac{dx_B}{dx_A}\frac{\partial \pi_A}{\partial x_B}. \tag{2.18}$$

To determine the sign of the subsidy, I have to investigate the sign of the two terms of the right hand side, corresponding to the strategic nature of the investments and the friendliness of the investments respectively. Firstly, the investments are strategic substitutes which is implied by a negative slope of the reaction function. Secondly, the investments are unfriendly as $\partial \pi_A \,/\, \partial x_B = -\frac{2}{3} q_A < 0$. If, for example, firm A increases its investment, its marginal costs fall which yields a larger share of the market and thus higher profits to firm A. Taking together the two effects of the investments, the optimal subsidy is positive.

In Brander and Spencer (1983), the optimality of an investment subsidy is shown in a more general model but for the same reasons: unfriendly investments

[9] A derivation of the optimal subsidy can be found in appendix C in the chapter 3.

and strategic substitutes. In table 2.1 I summarize the possible signs of the optimal policy arising if the structure is as in equation (2.18). The reason for the signs is as follows. If a government supports its domestic firm, it has an impact on the strategy of the foreign firm. If the investments are strategic substitutes, the foreign firm plays a less aggressive strategy, whereas if the investments are strategic complements, the foreign firm plays a more aggressive strategy. The strategy of the foreign firm, however, has an impact on the domestic firm's profits, which the government wants to maximize. If the foreign firm plays a more aggressive strategy the domestic firm's profits increase if the strategies are friendly, whereas the domestic firm's profits decrease if the strategies are unfriendly. In the above example of cost reducing R&D, a subsidy reduces the investment of the foreign firm because the investments are strategic substitutes. The profits of the domestic firm increase as the foreign firm decreases its investment because the investments are unfriendly.

The question remains as to whether a robust policy recommendation exists. To address this, the analysis has been extended in several ways. Bagwell and Staiger (1994) introduce uncertainty in the cost-reducing investments. They show that the results of a subsidy hold. In Brander (1995), the author notes that it is most likely for the investments to be unfriendly and strategic substitutes and thus a subsidy seems a fairly robust rule. Leahy and Neary (2001) reconsider the issue of robustness of the subsidy conjecture in general and for a variety of specific examples. They confirm the result of Brander (1995).[10]

2.3 Discussion

In this chapter I have introduced firstly the concept product differentiation with a representative consumer. I showed that there are two approaches, differing in how they treat the extension of the market size with product differentiation. Secondly, I reviewed the argument of strategic trade policy. The aspect of it that

[10] However, the result is limited by non-linearities.

becomes important is the strategic nature of the investment - whether they are strategic substitutes or strategic complements.

Stating a unique policy rule - a tax or a subsidy - is not possible. In the literature, despite ample research, no unifying set of policy recommendations exists. Although the arguments mainly favour a subsidy as a robust policy tool, exemptions exist. It is therefore of importance to investigate further policy intervention in international markets.

Chapter 3

Endogenous Product Differentiation and International Competition

3.1 Introduction

> *"The ranking of the top [competitiveness] priorities has remained..., with the low prices continuing to be rated as the lowest priority."* LABS 2006[1]

In this paper, I look at two aspects of horizontal product differentiation in international markets. Firstly, I consider the strategic decision of a firm to invest in differentiating its product. By investing in product differentiation a firm eases the competitive pressure. Secondly, I explore the possibility of a policy maker's strategic behaviour in the investment game when firms compete for a third market, increasing domestic welfare by subsidizing or taxing R&D investment in product differentiation of the domestic firm. I show that the optimal policy can involve either a subsidy or a tax, depending on a "market-expansion"

[1]London Annual Business Survey 2006; page 79.

effect.

In recent years, as a result of continuing trade liberalization, firms have faced stronger competition in international markets, to which they may respond in several ways. One avenue is to reduce costs in order to be able to compete with competitors' lower prices.[2] This is indeed an important strategy given the increased importance of offshoring to low cost locations. However, another important strategy for a firm is to differentiate its product from those of its rivals. In a survey by the City of London (2006), firms based in London rated performance strategies which are associated with product differentiation more highly than cost-reduction strategies. This is emphasized in table 3.1, which reproduces the data in the report with those priorities most strongly associated with product differentiation in bold. These numbers suggest that firms perceive it to be important to distinguish themselves from their competitors to an even greater extent than low prices. Furthermore, manufacturing firms on average rated the differentiation of their product as of higher importance in comparison with firms in other sectors.

In international trade, it is a common assumption that consumers value differentiated products.[3] One of the features of models with product differentiation is that each firm supplies a segment of the market and so possesses some degree of market power in it. In this paper, I develop a two-country model with each country hosting a single firm. Firms are able to invest in horizontally differentiating their product from that of the firm in the other country. The incentive for firms to invest in product differentiation is derived from the resulting decrease in competitive pressure and a consequential expansion of market power. The investments in product differentiation are modelled in a way such that the firms share the same degree of product differentiation. Therefore, the investments generate an externality which either firm can exploit by free-riding on the other firm's investment. I show that, in a strategic environment, firms have an incentive to

[2]As well, firms might want to set lower prices to gain a larger market share.

[3]The most prominent example is Krugman (1980).

Priorities	Mean Value
Quality of Product or Service	4.7
Customer Relations	4.6
Reliability of Product or Service	4.5
Established Reputation	4.5
Knowledgeable Staff	4.4
Speed of Delivery	3.9
Unique Product or Service	**3.9**
Product or Service Range	**3.7**
Design	**3.6**
Low Cost Base	3.5
Marketing	3.3
Low Prices	3.2

Priorities range from 1 to 5

Source: London Annual Business Survey 2006; page 79

Table 3.1: Strategic Priorities of Firms

reduce their investment in product differentiation in order to free-ride on their rival's investment.

In the literature on horizontal product differentiation, there are two examples of consumers' preferences with product differentiation. The formulation by Bowley (1924) has an expanding market size the more differentiated are the products, whereas in a formulation by Shubik and Levitan (1980) the market size remains constant. The difference in terms of the demand curve is as follows. Without the market-expansion effect, only the slope of the demand curve changes with a change in the degree of product differentiation. With a market-expansion effect, the demand curve shifts up or down as well as changing its slope with a change in the degree of product differentiation. The consumer preferences used in this model combine the two effects. This has the advantage of controlling for the degree of the market-expansion effect. The idea of the market-expansion effect is that, with a higher degree of product differentiation, consumers are willing to increase their spending in the relevant industry. The return on investment in product differentiation depends inter alia on the market-expansion effect.

I show that the strategic nature of the investments depends on both the degree of market-expansion and the free-riding incentive. With a strong market-expansion effect, the investments are strategic complements, which implies that the investments reinforce each other. If one firm makes an investment, the increase in the market improves the return on investment of the other firm. Therefore, the rival has an incentive to increase its investment. With a weak market-expansion effect, the investments are strategic substitutes. This implies that the investment of one firm reduces the investment of its rival. Therefore, if the market-expansion effect is weak it is dominated by the free riding incentive, whereas if it is strong, it dominates the free-riding incentive.

As I argue, firms face a strategic decision when investing in the R&D process. Can a policy maker intervene in the investment game to increase domestic welfare? Following Brander and Spencer (1983), I look at governments that have the option to subsidize or tax the investment in R&D by their domestic firm. By doing so, the policy maker directly influences the decision of the domestic firm to invest. The idea of this kind of policy intervention is that, by supporting the domestic firm, profits are shifted to the domestic firm from its rival. For example, by offering a subsidy, the domestic firm has a lower marginal cost of investment and thus increases its investment. In this paper, the motive for intervention is to increase the profits of the domestic firm. Due to government intervention, the domestic firm invests more in product differentiation. The more differentiated products are, the less competitive pressure firms face, which allows them to set an output which implies higher profits. Brander and Spencer (1983) show that the sign of the optimal policy depends on two aspects of the investments. The first aspect is whether the investments are "friendly" or "unfriendly". The investments are friendly if the profits of a firm are increasing in the investment of the other firm, whereas the investments are unfriendly if the profits of a firm are decreasing in the investment of the other firm. I show that in the present model, the investments are friendly. The second aspect is that the sign of the policy depends on the strategic nature of the investments. The definition I use for strategic nature of investments is found in Bulow, Geanakoplos, and Klemperer (1985), who define strategic complements (substitutes) as $\partial\pi_i \,/\, \partial S_i \partial S_j > 0 (< 0)$ where S_i is the strategy of firm i. In the present model I show that if the market-expansion effect is weak, the investments are strategic substitutes. If, on the other hand, the market-expansion effect is strong, the investments are strategic complements. I further show that the optimal policy is a subsidy if the investments are strategic substitutes and a tax if the investments are strategic complements.

In the literature, despite the wide use of the concept of product differentiation, little work is found on endogenous investment in product differentiation and strategic trade policy. On the side of the endogenous product differentiation, the work that is closest to investment game in the model is by Motta and Polo (1998). In their paper, two firms endogenously choose the degree of product differentiation. They assume that the market size remains independent of the degree of product differentiation and thus remains constant. Accordingly, the investments are strategic substitutes, whereas in the current work they can be strategic complements.

On the side of strategic trade policy, extensive work has been done.[4] However, there is a lack of a unifying set of policy recommendations for supporting domestic firms in international markets. Leahy and Neary (2001) try to find robust recommendations as to whether a subsidy or tax is the optimal policy. They show in a wide array of specific models that a subsidy is most often the optimal policy.

[4] For example, Brander and Spencer (1983), Brander and Spencer (1985), Dixit (1984), Bagwell and Staiger (1994), Brander (1995), Eaton and Grossman (1986), Maggi (1996) or Neary and Leahy (2000).

The reason is that either the investments are unfriendly and strategic substitutes or friendly and strategic complements. One of the special cases in Leahy and Neary (2001) examines market-expansion investment. The authors conclude that "a positive investment subsidy is once again optimal". I add a case in which the investments are always friendly, but the sign of the optimal policy is ambiguous and depends on the size of the market-expansion effect.

In the first section of the paper, I develop a specific model of endogenous product differentiation to introduce the market-expansion effect. In the second part of the paper, I generalize this model and show the conditions under which the results from the first section hold. In addition, I introduce a government policy and investigate its impact on the investment game. In the third section, I look at optimal government policy.

3.2 A Model of Product Differentiation

3.2.1 Demand

In this subsection, I discuss the underlying utility function and the resulting demand functions of the model. The basic set-up is a Cournot duopoly where two firms compete for a third market. Each firm is hosted by a different country $i = A, B$. The representative consumer in the third market views the output of each firm, q_i as horizontally differentiated. The utility function takes the form

$$U = a(q_A + q_B) - b(1 + \sigma(1 - \theta))\left(\frac{q_A^2}{2} + \frac{q_B^2}{2}\right) - b\theta q_A q_B + m \tag{3.1}$$

where $\theta \in (-\infty, 1]$ is the degree of product differentiation. The parameter $\sigma \in [0, 1]$ measures the degree of the market-expansion effect. The utility function is quasi-linear in m which is chosen as the numeraire. Given the quasi-linear nature of the utility function there are no income effects. Consumers optimize their consumption of good A and B and spend the rest of their income on the numeraire good. The utility function exhibits a taste for variety by the consumer, given by the first two terms on the right-hand side. The third term is a competition term. The more differentiated the products are, the less competition there is amongst the two firms.

The resulting inverse demand function for good $i = 1, 2$ and $j \neq i$ is

$$p_i = a - \alpha b q_i - b\theta q_j \tag{3.2}$$

where $\alpha \equiv 1 + \sigma(1 - \theta)$. If $\theta \in [0, 1)$ the goods are imperfect substitutes. If θ is close to zero, the goods are highly differentiated and thus the firms are close to being monopolists in separate markets. The upper bound, θ close to one, implies the goods are closer to homogeneous goods and thus the firms face fiercer competition. If $\theta = 1$ the goods are perfect substitutes. For $\theta < 0$ the goods become complements. The intuition for the market-expansion effect is as follows. A change in the degree of product differentiation has two effects on the individual demand curves. Firstly, it alters the slope of the demand curve and secondly, the vertical intercept of the demand curve - the choke price - changes, which shifts the demand curve. If the market-expansion effect is weak, the shift of the demand curve is small. In the case of no market-expansion effect at all, the demand curve does not shift and only the slope of it is affected by product differentiation. The degree of the market-expansion effect controls for the strength of the shift of the demand curve. The upper boundary of σ corresponds to no market-expansion effect at all.

3.2.2 Firm Behaviour

The degree of differentiation is a function of the firms' investments and is assumed to take the form

$$\theta(x_A, x_B) = \max\{0, 1 - x_A - x_B\}. \tag{3.3}$$

If no firm makes an investment, the outputs are assumed to remain homogeneous, $\theta = 1$. I assume that the degree of product differentiation cannot become negative. This implies that I rule out that the outputs are complements.[5] The restriction implies that the two firms remain competitors in the market, although

[5]Complementary outputs might be analysed in future work.

product differentiation eases the competitive pressure. From an economic perspective, a situation in which firms produce substitutes prior to the investment, but differentiate their products so much that the products become complements is hard to imagine. By making this restriction, I consider an aggregate investment of $x_A + x_B > 1$ as wasteful, as it has no additional effect on the degree of differentiation. In a numerical simulation exercise below, I will show that the set of aggregate investment satisfying $x_A^* + x_B^* \leq 1$ in equilibrium is non-empty.

Both firms face the same θ. Investments have a positive externality: if a firm invests in differentiating its output, it reduces the competitive pressure on its rival. Each firm can make an investment in differentiating its output from its rival. This investment is costly, with a convex cost function $g_i = \gamma x_i^2$.[6] The parameter $\gamma \in [0, 1]$ indicates the efficiency of a firms investment, which is assumed to be the same for both firms. The marginal costs of producing the output are denoted by c. Therefore, the firms are symmetrical with respect to the costs.

The game is one of complete but imperfect information. The structure of the game and the profit functions of each firm are common knowledge. Further, decisions become common knowledge as soon as they are implemented. At each point in time firms move simultaneously. The timing of the game is as follows: (1) the firms make an investment to differentiate their product; (2) the firms play a Cournot quantity game. The whole game is solved backwards. At each stage of the game, the firms play subgame-perfect strategies. After the firms have chosen their investments, these are treated as fixed costs. Let

$$\pi_i = (p_i - c)q_i - \gamma \frac{x_i^2}{2} \quad i = A, B, \tag{3.4}$$

denote the profit of a firm.

[6] Convex investment costs is an assumption regularly made in the R&D investment literature.

The Second Stage Output Game

In the second stage of the game, each firm maximizes net profits with respect to the output, taking the investments in product differentiation as given. The net profits are profits less the investment costs. This results in the following reaction functions of output

$$q_i = \frac{a-c}{2\alpha b} - \frac{\theta}{2\alpha} q_j \tag{3.5}$$

The degree of product differentiation affects the output response of firm i in two ways. Firstly, as indicated by the term $(2\alpha)^{-1}$, the slope of the demand function for good i changes. With a higher degree of product differentiation, the demand curve becomes flatter. Secondly, as indicated by the term θ, with a higher degree of product differentiation the competition from the rival becomes less strong. The total effect of product differentiation on the reaction function is ambiguous, as the two effects have opposing signs. However, as will be apparent below from the expression of the optimal output, in equilibrium the second effect dominates. A comparison to cost-reducing R&D reveals that the strategic term, the equivalent to the second term, is not affected by the investment in lower marginal costs. Therefore, the investments in marginal costs shift the reaction function of a firm without changing its slope, whereas if firms invest in product differentiation, the slope of the reaction function changes as well.

The unique symmetric Nash equilibrium in the second stage is

$$q_i^* = \frac{a-c}{b(2\alpha+\theta)} \quad i = A, B. \tag{3.6}$$

The change of q_i^* with the degree of product differentiation depends on the extent of the market expansion effect. If $\sigma > 1/2$, the output decreases with θ and increase otherwise.[7] Substituting the optimal outputs (3.6) into the profit function of firm i (3.4) I obtain the third stage profits

$$\pi_i^* = \frac{\alpha}{b}\left(\frac{a-c}{2\alpha+\theta}\right)^2 - \gamma x_i^2 \quad i = A, B. \tag{3.7}$$

[7]Formally this can be see by computing $dq_i^*/d\theta = -(1-2\sigma)([a-c]/[b(2\alpha+\theta)]^2)$.

The Investment Game

Having solved for the second stage equilibrium I now consider the actions of the firms in the first stage. A firm chooses the optimal investment up to the point where marginal net profit equals marginal costs of investment. When maximizing profits, firm i faces two constraints. Firstly, the way the investment maps into the degree of product differentiation, which is given in equation (3.3) . Secondly, the outputs cannot become complements. The formal problem is

$$\begin{array}{ll} \max_{x_i} & \pi_i = \frac{\alpha}{b}\left(\frac{a-c}{2\alpha+\theta}\right)^2 - \gamma x_i^2 \\ \text{subject to} & \theta = \max\{0, 1 - x_A - x_B\} \end{array}$$

where the constraint is the mapping of the investments to the degree of product differentiation. In the remainder of this section, I assume that the constraint always holds for the parameters in the model. Below, I will show the existence of such investments in a numerical example. Hence, I substitute the constraint into the profit function. The first-order condition for the optimal investment is

$$(\theta\sigma + 2\alpha(1-\sigma))\frac{(a-c)^2}{b(2\alpha+\theta)^3} - 2\gamma x_i \quad = \quad 0 \quad i = A, B \tag{3.8}$$

which is an implicit reaction function for the investment of firm i as $\theta(x_A, x_B)$ is a function of the investments. The shape of the reaction function depends on the parameter values of c and γ. For example, an increase in the efficiency of the investment (lower γ) reduces the marginal investment costs and thus increases the investment in product differentiation.

In this section, I am interested in the strategic nature of the investments in product differentiation. Let $\pi_i^{ij} \equiv \partial^2\pi_i \,/\, \partial x_i \partial x_j$. I approximate the strategic nature by the slope of the reaction functions, which is

$$\frac{dx_i}{dx_j} = -\frac{\pi_i^{ij}}{\pi_i^{ii}} \quad i = A, B. \tag{3.9}$$

The full derivation of the slope is given in the appendix. The determinant is positive if $\pi_A^{AB} = \pi_B^{BA} > \gamma$, which is derived in the appendix as well. Therefore, the slope of the reaction function depends on the cross derivative of the profit function. In general, each firm is exposed to two effects which have an opposing effect on the investment incentives. The effects are an incentive to free-ride on the rival's investment and an incentive to increase the size of the market. Due to the spillover of the investments in product differentiation each firm has an incentive to free ride on its rival's investment; if one firm differentiates itself it implicitly differentiates the product of the other firm. Therefore the rival benefits from the differentiation and could even reduce its own investment in order to maintain the level of product differentiation. The market-expansion effect increases the size of the market and thus makes it viable for the firm to invest more.

In figure 3.1, I numerically simulate the first-order conditions to show the effect of the market-expansion effect on the slope of the reaction function. The results of the parameterization remains robust to variations in their neighbourhood. Additionally, as I show in the next section, the results can be generalized. In the figure, I depict the reaction functions for three different values of σ. In the sequel of the section I discuss, the three resulting reaction functions and the economic intuition of them. With a strong market-expansion effect, $\sigma < \frac{1}{2}$, the reaction function is upwards sloping. Accordingly, the investments are strategic complements. With strategic complements, a higher investment by one firm increases the marginal return to investment of the other firm. In the case under consideration, the market-expansion effect is strong and dominates the free-riding effect. This leads to a mutual reinforcement of the investments. I should point out that, as can be seen from figure 3.1, the slope of the strategic complements is declining and a turning point exists at which the reaction function is negatively sloped. However, this part of the reaction function is not of interest here as potential equilibria are not stable.

In the special case of $\sigma = \frac{1}{2}$, the free-riding incentive and the market-expansion effect are of equal strength and cancel each other out. Accordingly, the investment of one firm is independent of the action of the rival and merely a function of the parameters of the model. With a weak market-expansion effect, $\sigma > \frac{1}{2}$,

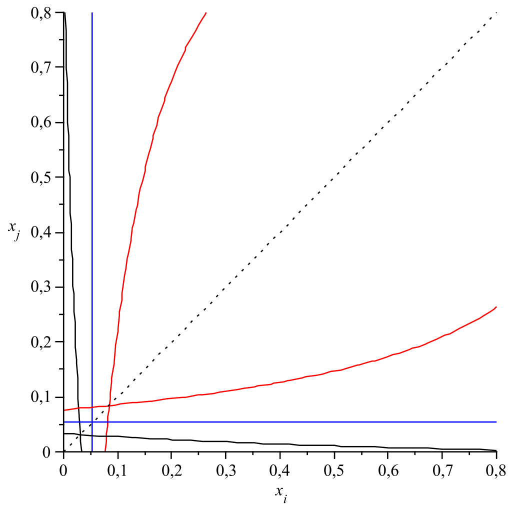

Figure 3.1: First Order Conditions

the reaction function is downwards sloping. Accordingly, the investments are strategic substitutes. With strategic substitutes, a higher investment by one firm decreases the marginal return to investment of the other firm.

To summarize the findings of this subsection, I showed that the strategic nature of the investment depends on the market-expansion effect. Intuitively, this can be explained as follows. Firms have an incentive to free-ride on the investment of their rival, due to the externality of product differentiation. This effect implies that the investments have the tendency to be strategic substitutes because a higher investment by one firm reduces the incentive to invest of the rival firm. However, the market-expansion effect has the externality on consumers that they increase their spending in both markets. This effect implies that there is some complementarity between investments, as a larger market implies an increase in the marginal return to investment. Thus, if the market-expansion effect is strong enough, the investments are strategic complements.

3.3 A Generalization

3.3.1 The General Model

In this section, I develop a generalization of the model in the previous section. In the previous section, the functional forms of the demand function and the degree of product differentiation were quite specific. With the generalization I show that the results obtained in the specific model are valid considering a larger class of functional forms. To this end, I generalize the conditions under which an equilibrium in the investment game exists and show that these conditions give rise to the strategic nature of investments depending on the market-expansion effect.

I do not explicitly consider a generalized solution to the quantity game in the third stage. I assume, however, the existence of a stable solution.[8] Let $R_i \equiv R(q_A^*, q_B^*; \theta)$ denote the subgame perfect net revenues of the quantity game. In the second stage, the quantities are chosen given the inverse degree of product differentiation θ. Subsequently, I rewrite subgame perfect quantities in the second stage as $q_i = q_i(\theta)$. The mapping of the investment into the inverse degree of product differentiation is assumed to be $\theta \equiv \theta(x_A, x_B)$. As the second stage involves choosing the optimal investment, I rewrite the net profits as $R_i = R_i(\theta)$. θ is the only argument in the revenue function as quantities are chosen in the third stage taking the investments in product differentiation as given. The investment costs are denoted by $C_i \equiv C_i(x_i)$. Accordingly, the profit function in the second stage is

$$\pi_i(x_1, x_2) = R_i(\theta) - C_i(x_i). \tag{3.10}$$

To characterize the equilibrium in the investment game, I need to impose some assumptions on the curvature of the underlying functional forms.

[8]Brander and Spencer (1983) show the conditions under which an equilibrium in the quantity game exists. Restating their derivation does not provide any extra information.

Assumption 1. *Functional restrictions*

$$\frac{\partial R_i}{\partial \theta} < 0 \qquad \frac{\partial^2 R_i}{\partial \theta^2} \lesseqgtr 0 \tag{3.11}$$

$$\frac{\partial C_i}{\partial x_i} > 0 \qquad \frac{\partial^2 C_i}{\partial x_i^2} > 0 \tag{3.12}$$

$$\frac{\partial \theta}{\partial x_i} < 0 \qquad \frac{\partial^2 \theta}{\partial x_i^2} \geq 0. \tag{3.13}$$

The first line (3.11) defines the effect of product differentiation on the first stage net revenues, noting that more product differentiation corresponds to a lower θ. The first condition states that the more differentiated the products, the more the net revenues increase. The second condition is the second order effect of the inverse product differentiation on the net revenues, which I assume is undetermined in its sign. This assumption is at the core of the paper. In Motta and Polo (1998) the equivalent derivative is assumed to be negative. In their paper, this implies that the net revenues are concave in the (inverse) degree of product differentiation. However, the interpretation of the second order derivative in this paper is as follows. A negative sign implies a weak market-expansion effect, whereas a positive sign implies a strong market-expansion effect. For example, with the market-expansion effect, the direct effect of more product differentiation is an increase in the marginal revenue because there is not only less competition for the market, but the market size has increased.[9]

The second line (3.12) defines the investment costs to be convex in the investment, which is a common assumption in the literature on R&D. The third line (3.13) defines the effect of the investment on the inverse measure of product differentiation. The first condition states that the investment differentiates the products more and the second condition states that it does so at a non-increasing rate. Further, I assume that $\partial \theta \,/\, \partial x_i|_{\sum x_i = 0} \in (0, \infty)$.

[9] Note that the marginal revenue is negative.

Assumption 2. *The symmetry of the investment*

$$\frac{\partial\theta}{\partial x_i} = \frac{\partial\theta}{\partial x_j} \tag{3.14}$$
$$\frac{\partial^2\theta}{\partial x_i^2} \geq \frac{\partial^2\theta}{\partial x_j \partial x_i} \tag{3.15}$$

The first line (3.14) states that the degree of product differentiation is symmetrical in the investments. The second line (3.15) governs the investment spillovers. I assume that the change in the marginal investment is not less than the effect of an investment made by the other firm on the marginal investment. This is a standard assumption in the literature on R&D investment, which allows for the different weight of the investment spillovers. I follow the literature and do not restrict the derivatives to equal weights of the investments.

Having made all the necessary assumptions, I now characterize the solution to the investment game in the second stage. In this stage, the firms maximize profits with respect to their investments. The first order condition is

$$\pi_i^{i*} = \frac{\partial R_i}{\partial\theta}\frac{\partial\theta}{\partial x_i} - \frac{\partial C_i}{\partial x_i} = 0. \tag{3.16}$$

Note that the first term is larger than zero, given the assumptions on the derivatives made. To ensure that a maximum exists, the second order condition must hold and be negative. Formally this implies that

$$\pi_i^{ii} = \frac{\partial^2 R_i}{\partial\theta^2}\left(\frac{\partial\theta}{\partial x_i}\right)^2 + \frac{\partial R_i}{\partial\theta}\frac{\partial^2\theta}{\partial x_i^2} - \frac{\partial^2 C_i}{\partial x_i^2} < 0. \tag{3.17}$$

The first two terms on the right hand side are the marginal return on investment. The first term of the marginal return on investment denotes the direct effect on the marginal revenue, which is the market-expansion effect. The second term denotes the non-increasing effect of the investment on the inverse degree of product differentiation. Hence, it is not becoming easier to differentiate the output the higher the investment becomes. The second and the third term of the second order condition are negative. The sign of the first term depends on the sign of $\partial^2 R_i \,/\, \partial\theta^2$. If the latter derivative is smaller than zero, the second order condition holds without further restriction. In other words, if the market weakly expands with the degree of product differentiation, the profit function is concave and the investment problem has a solution. If the derivative is positive, it must be small enough for the second order condition to hold. Therefore, if the market-expansion effect is small enough, the investment problem is well behaved and a solution exists.

I now investigate whether the solutions to the investment game are unique. By Cramer's rule, I know that the solution to the investment game is unique if the determinant $D = \pi_i^{ii}\pi_j^{j} - \pi_i^{ij}\pi_j^{ji}$ non-zero. To this end I assume that the cross effect is smaller than the own effect of the investment $\pi_i^{ii} < \pi_i^{ij}$. Substituting the derivatives into the latter inequality yields

$$\frac{\partial R_i}{\partial \theta}\left(\frac{\partial^2 \theta}{\partial x_i^2} - \frac{\partial^2 \theta}{\partial x_j \partial x_i}\right) - \frac{\partial^2 C_i}{\partial x_i^2} < 0. \tag{3.18}$$

This inequality holds as long as assumption 1 and 2 is satisfied.

Previously, I showed that if the profit function is concave in θ and the determinant is non-zero. If these conditions are met, a solution to the investment game exists and is unique. I now prepare the grounds for the policy section.

Lemma 1. *The profits of one firm increase in the investment of the other firm. Therefore the investments are friendly.*

Proof.

$$\frac{\partial \pi_i}{\partial x_j} = \frac{\partial R_i}{\partial \theta}\frac{\partial \theta}{\partial x_j} > 0 \quad i = A, B$$

□

A strategy of a firm is called friendly if it increases the profits of the other firm[10]. The derivative in the proof above is the definition of a friendly investment.

The slope of the reaction function is given by (3.9). The sign for the numerator is negative, which is implied by assumption of the concavity of the profit function.

[10]Note that the concept of friendliness refers to pure profits whereas the strategic nature of the investment refers to marginal profits.

In order to determine the sign of the denominator, I look at the derivative in the denominator, which is

$$\frac{\partial^2 R_i}{\partial \theta^2}\left(\frac{\partial \theta}{\partial x_i}\right)^2 + \frac{\partial R_i}{\partial \theta}\frac{\partial^2 \theta}{\partial x_j \partial x_i}. \tag{3.19}$$

The second term is not positive, whereas the sign of the first term depends on the market expansion effect. With a weak market expansion effect, the term is negative and the slope of the reaction function is negative. Therefore, the investments are strategic substitutes. The economic intuition is that firms have a strong incentive to free ride on the rival's investment. With a strong market expansion effect, the term might be positive and the overall term might turn positive as well without violating the second order condition. Therefore, the slope of the investment reaction function is positive with a strong market-expansion effect and investments are strategic complements. The reason is that marginal return from product differentiation increases with a larger investment.

Corollary 1. *Depending on the market-expansion effect the investments are strategic substitutes or strategic complements*

Proof. See equations (3.9) and (3.19). □

How does the specific model compare to the general model? For the first set of restrictions in assumption 1, all derivatives in the specific model hold. The sign of the second derivative in line (3.11) is ambiguous; however, it is larger than zero if $\sigma = 0$, where the latter condition implies a strong market expansion effect. The investment costs in the specific model are convex, which satisfies the restrictions in (3.12). The derivative in line (3.13) is zero in the specific model and thus holds with equality. The second set of restrictions in assumption 2 are met in the following way. The first line (3.14) holds in the specific model. The second line (3.15) holds with equality in the specific model. Therefore, the investments have the same weights in the degree of product differentiation. The results of the model are similar as well. For example, a large market-expansion effect implies strategic complements, whereas a weak market-expansion effect implies strategic substitutes.

3.4 Policy Intervention

In this section, I investigate how a policy maker can intervene in the investment game to increase domestic welfare. In particular, I look at a R&D policy. In the derivation of the policy schedule, I employ the techniques developed in Brander and Spencer (1983). Prior to deriving the policy schedule, I develop some comparative statics which are needed in the section.

In addition to the two stages I introduce a pre-firm stage in which the governments announce their policy to support the respective domestic firm. The policy parameter is denoted by λ_i. The policy is assumed to take the form of a subsidy or a tax to the investment costs of the domestic firm. In the case of $\lambda_i < 0$ the firm would pay a tax, whereas $\lambda_i > 0$ corresponds to a subsidy. The policy is paid per unit of investment and therefore proportional to the investment. A R&D policy does not directly change the output game; it indirectly influences the output decision by a firm by altering the decision to invest in product differentiation. I assume that a policy maker credibly announces the policy schedule. Due to subgame perfection, a policy maker anticipates the behaviour of the firms. Additionally, I assume that the policy maker has complete information of the game. The order of the stages is as follows. The government moves first and announces its policy schedule. In the second stage, the firms choose their investment, given the government policy. In the third stage, the firms set quantities, given the investments in product differentiation. In each stage, the players move simultaneously and observe the actions taken in previous stages of the game.

For simplicity, I only introduce the policy in the general model. The specific model of section 3.2 yields the same qualitative results. The profit function of a firm changes as follows

$$\pi_i(x_1, x_2) = R_i(\theta) - C_i(x_i) + \lambda_i x_i. \tag{3.20}$$

The first-order condition is

$$\pi_i^{i*} = \frac{\partial R_i}{\partial \theta}\frac{\partial \theta}{\partial x_i} - \frac{\partial C_i}{\partial x_i} + \lambda_i = 0. \tag{3.21}$$

The effect the policy schedule has on the reaction function is as follows. Depending on the sign of the policy, the reaction function shifts in or out without changing the slope of the reaction function. For example, a subsidy shifts the reaction function outwards, implying a higher investment in product differentiation. Further, the reason for the constant slope of the reaction function 3.9 is that the second-order condition (3.17) and the cross derivative in (3.18) do not change. Therefore, the results derived in the previous section, especially on the strategic nature of the investments, do not change with the introduction of a policy.

How are firm's investments responding to a policy? To answer this question I assume that only the government in i announces a policy. Totally differentiating the first order conditions of the investment, I obtain the following matrix

$$\begin{pmatrix} \pi_i^{ii} & \pi_i^{ij} \\ \pi_j^{ji} & \pi_j^{jj} \end{pmatrix} \begin{pmatrix} \frac{dx_i}{d\lambda_i} \\ \frac{dx_j}{d\lambda_i} \end{pmatrix} = \begin{pmatrix} -1 \\ 0 \end{pmatrix}. \tag{3.22}$$

I assume that the determinant $D = \pi_i^{ii}\pi_j^{jj} - \pi_i^{ij}\pi_j^{ji}$ of the matrix is positive to ensure a unique solution. Accordingly, the investment responses of the firms to a policy are

$$\begin{aligned} \frac{dx_i}{d\lambda_i} &= -\frac{\pi_i^{ii}}{D} \\ \frac{dx_j}{d\lambda_i} &= \frac{\pi_j^{ji}}{D} \end{aligned} \tag{3.23}$$

The investment response of firm i to an increase in the policy is positive. The response of firm j depends on the cross derivative of its profit function. This is similar to slope of the reaction function in (3.9) which depends on the cross derivative as well. If the investments are strategic complements, then the market-expansion effect dominates and a subsidy for firm i, which implies a higher investment, means a higher marginal return on investment for firm j. If the investments are strategic substitutes, the market-expansion effect is relatively small and the marginal return on investment is hampered.

Corollary 2. *The investment response of firm i to a policy is unambiguously positive. The investment response of firm j is negative if the market-expansion effect is weak and positive if the market-expansion effect is strong.*

Proof. see equation (3.23) and (3.9). □

The relative investment gap is given by $(\partial x_j \,/\, \partial \lambda_i) \,/\, (\partial x_i \,/\, \partial \lambda_i) = -\pi_j^{ji} \,/\, \pi_j^j$, which I rewrite as

$$\frac{dx_j}{dx_i} = \frac{\partial x_j \,/\, \partial \lambda_i}{\partial x_i \,/\, \partial \lambda_i} \tag{3.24}$$

3.4.1 Unilateral Policy Intervention

I start off with the simplest case of a unilateral policy. In this subsection, I assume that only country A has an active government such that $\lambda_B = 0$. The policy maker in the active country chooses the policy that maximizes national welfare. Because firms compete for a third market, I can neglect consumer surplus in the domestic market. Thus welfare is the profit level of the firm less the total subsidy payments to the firm

$$W_A = \pi_A(x_A, x_B) - \lambda_A x_A, \tag{3.25}$$

where the investments are a function of the subsidy, $x_i = x_i(\lambda_A)$ for $i = 1, 2$. I derive the optimal policy in a general way, using the specific functions of the previous model to determine the signs of the derivatives. Totally differentiating the welfare function (3.25), substituting equation (3.24) and using the envelope theorem yields[11]

$$dW_A = \pi_A^B dx_B - \lambda_A dx_A. \tag{3.26}$$

To obtain the optimal policy, I have to set $dW_A = 0$ and rearrange the latter expression which returns the optimal policy

$$\lambda_A = \pi_A^B \frac{dx_B}{dx_A}. \tag{3.27}$$

As in Brander and Spencer (1983) the optimal schedule depends on the slope of the reaction function and the friendliness of the investments.

Lemma 2. *A government has the incentive to set an optimal unilateral policy, which is a subsidy if the investments are strategic complements and a tax if the investments are strategic substitutes.*

[11] A more detailed derivation is found in the appendix.

Proof. The sign in 3.27 is determined by lemma 1 and equation (3.9). □

The intuition for the lemma is as follows. From equation (3.27), I see that the sign of the optimal policy depends on the friendliness of the investment and the strategic nature. The investments are always friendly because of the externality of product differentiation. The strategic nature depends on the extent of the market-expansion effect. As discussed in the specific model, if the market-expansion effect is strong, the investments are strategic complements. Thus a government improves the situation of the firm by inducing a larger market via an investment subsidy. If the market-expansion effect is dominated by the free-riding incentive, the policy maker tries to exploit the latter effect by inducing a lower investment of its domestic firm via an investment tax.

3.4.2 A Nash Subsidy Game

In this section, I analyze a policy rivalry between the two countries. Both governments are able to support their respective firm by announcing a policy schedule for R&D. Each government maximizes its respective domestic welfare function

$$W_i = \pi_i(x_A, x_B) - \lambda_i x_i \quad \forall i = A, B. \tag{3.28}$$

The timing of the whole game remains unchanged and both governments announce their policy simultaneously. The first order condition for the welfare maximum is $dW_i = \pi_j^i dx_j - \lambda_i dx_i = 0$ for $i = A, B$, which has the same structure as the previous welfare optimum but with a different solution. To obtain an expression for the change of the investment in the policy, I rewrite the second derivative in matrix form

$$\begin{pmatrix} \pi_i^{ii} & \pi_i^{ij} \\ \pi_j^{ji} & \pi_j^{jj} \end{pmatrix} \begin{pmatrix} \frac{\partial x_i}{\partial \lambda_i} \\ \frac{\partial x_j}{\partial \lambda_i} \end{pmatrix} = \begin{pmatrix} -1 \\ -1 \end{pmatrix}. \tag{3.29}$$

Using Cramer's rule, I derive the optimal subsidy

$$\lambda_i = \pi_i^j \frac{dx_i}{dx_j}. \tag{3.30}$$

Note that the structure is the same as for the unilateral subsidy. However, the values of the right hand side are different. The sign of the subsidy is the combined effect of the impact of the foreign investment on the profits and the slope of the reaction function.

Proposition 1. *The optimal Nash policy is a tax if the market-expansion effect is weak and a subsidy if the market-expansion effect is strong.*

The optimal policy is a tax if the market-expansion effect is weak. The intuition is that the investments provide an incentive to free ride as they have a positive externality on the other firm. Additionally, the reaction functions are downwards sloping. Therefore, if a government can influence its domestic firm to reduce the investment, the investment of the foreign firm will go up. This in turn implies that the profits of the domestic firm increase because the investments are friendly. Considering a strong market expansion effect, the optimal policy is to subsidize the investments. The intuition is that the effect of the larger market is stronger than the incentive to free ride on the other firm's investment. Thus, if a government subsidizes its own firm, the other firm increases its investment as well, leading to a larger market.

A subsidy is in line with Brander and Spencer (1983). In their model, a policy maker has an incentive to announce a subsidy to increase the R&D investments of the home firm. I find a similar result for a small market-expansion effect. However, with a large market-expansion effect, I find that a tax is optimal. This is at odds with Brander and Spencer (1983). The difference is explained by the friendliness of the investments and the ambiguity of the strategic nature of the investments due to the market-expansion effect. Leahy and Neary (2001) generalize the conditions under which a subsidy is optimal. They conclude that a subsidy is a robust rule.[12] The results found in this paper show that, in a different set up, this proposition might not hold. The reason is the strategic nature of the investments.

[12] With the exception of non-linearities in the demand function.

3.4.3 The Cooperative Policy

I now analyze what the optimal policy is if both countries collude. I do so by comparing the optimal policy derived previously to a cooperative policy. To this end, I assume that both countries coordinate their policy efforts and maximize joint welfare, $W(\lambda_A, \lambda_B) = W_A + W_B$. From the first order conditions of the welfare maximum, I obtain

$$\lambda_i = \pi_i^j \quad \forall i = A, B \tag{3.31}$$

The derivation is found in the appendix.

Proposition 2. *The optimal policy under joint welfare maximization is to subsidize the investments in product differentiation.*

Proof. See equation (3.31) and lemma 1. □

This result is obtained regardless of the strategic nature of the investments. Intuitively, the joint government take into account the positive externality of the investment on each other's profits. By subsidizing the investments, each firm increases not only the profit of its own firm but these of the other country as well. Accordingly, welfare increases and governments exploit this externality. In Brander and Spencer (1983) the optimal cooperative policy is a tax. The reason for the difference is that the investments are unfriendly in Brander and Spencer (1983).

3.5 Conclusion

In this paper, I introduced a model of strategic horizontal product differentiation. In the first stage, firms choose their investments in product differentiation. The strategic nature of the investment depends on whether the market-expansion effect dominates the free-riding incentive or vice versa. In the former case, investments were strategic complements, in the latter they were strategic substitutes. I showed this in both a specific and a general model. Then I went on to introduce a pre-firm stage where a policy maker announced a policy schedule. I showed that a subsidy is optimal in the case of strategic substitutes and a tax is optimal in the case of strategic complements. The existing literature on strategic trade policy suggested that a subsidy is a robust policy tool. In this work, I showed that this conclusion is supported if the investments are strategic substitutes. However, if the investment are strategic complements, the conclusion of the literature cannot be supported.

Appendix

The Slope of the Reaction Function

Let $\pi_i^{ii} = \frac{\partial^2 \pi_i}{\partial x_i^2}$ denote the second order derivative of the profit function with respect to the investment and let $\pi_i^{ij} = \frac{\partial^2 \pi_i}{\partial x_i \partial x_j}$ denote the second order cross derivative for $j \neq i$. Then I write the expression as

$$\begin{pmatrix} \pi_i^{ii} & \pi_i^{ij} \\ \pi_j^{ji} & \pi_j^{jj} \end{pmatrix} \begin{pmatrix} dx_i \\ dx_j \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}. \tag{3.32}$$

For stability, the determinant of the matrix must satisfy $D = \pi_i^{ii}\pi_j^{jj} - \pi_i^{ij}\pi_j^{ji} > 0$. Due to the symmetry of the model $\pi_i^{ii} = \pi_i^{jj}$ and $\pi_i^{ij} = \pi_j^{ji}$ holds. Rewriting the latter equation as $\pi_i^{ij} = \pi_j^{ji} > \gamma$ is equivalent to the condition in Lemma 1. Solving the above matrix yields the slope of the reaction function.

The Optimal Subsidy

I rewrite the profit function of firm i as $\pi^i = \pi^i(x^i(\lambda_i), x_j(\lambda_i))$. Thus the welfare function is a function of the subsidy only $W = W(\lambda_i)$. Accordingly, I differentiate the welfare function with respect to the subsidy which yields

$$\frac{\partial W}{\partial \lambda_i} = \pi_i^i x_s^i + \pi_j^i x_{\lambda_i}^j + \pi_{\lambda_i}^i - x^i - \lambda_i x_{\lambda_i}^i.$$

From the firm's problem, I know that $\pi_i^i = 0$. Further, $\pi_{\lambda_i}^i = x^i$ from the profit function of firm i. Then I make use of the relative investments $x_{\lambda_i}^j = x_{\lambda_i}[dx^j/dx^i]$, which yields the desired result.

The joint welfare function is $W(\lambda_A, \lambda_B) = W_A + W_B$. The first order condition of the maximization are $dW/d\lambda_A = 0$ and $dW/d\lambda_B = 0$. As before, taking into account that $\pi_i^i = 0$, $\pi_{\lambda_i}^i = x^i$ and $x_{\lambda_i}^j = x_{\lambda_i}[dx^j/dx^i]$ yields the equations

$$\begin{aligned} \lambda_A + \lambda_B \tfrac{dx_B}{dx_A} &= \pi_A^B + \pi_B^A \tfrac{dx_B}{dx_A} \\ \lambda_B + \lambda_A \tfrac{dx_A}{dx_B} &= \pi_B^A + \pi_A^B \tfrac{dx_A}{dx_B}. \end{aligned} \tag{3.33}$$

The equations are solved simultaneously which yields $\lambda_A = \pi_A^B$ and $\lambda_A = \pi_A^B$.

Part II

Growth and Offshoring

Chapter 4

The Theory of Growth and Offshoring

The idea developed in Part II of this thesis is that offshoring increases growth. In endogenous growth models, the allocation of factors of production to R&D matters. In the literature, the growth rate of an economy generally depends on the total factor endowment, where a larger factor endowment implies a higher growth rate. Due to offshoring, jobs are moved abroad and those factors of production previously employed in those jobs are now available for reallocation in the economy. If those freed factors are reallocated towards R&D, the growth rate of the country might increase.

In this chapter, I review the literature on growth and offshoring. The growth literature is reviewed with special focus on the effect of factor endowments on the growth rate. I then turn to the discussion of offshoring, focusing on a particular type of offshoring called "trade in tasks". I demonstrate the main argument of chapters 5 and 6 in a highly stylized model. Both literature reviews are far from exhaustive, but serve to introduce the main argument of Part II of this thesis.

4.1 Growth

This section focuses on introducing the different growth mechanisms discussing their dependency on the factor endowments in the economy. I briefly discuss the effect of the set-up of a model on the structure of the growth rate. I additionally show whether economies might diverge in their growth paths if they trade internationally.

Growth theory is a long-standing topic in economics. The early approaches were unsatisfactory to explain differences in growth rates because they were assumed to be exogenous.[1] Therefore, economists attempted to endogenize the rate of growth of an economy. One of the lessons learned from the Solow model was that capital exhibits diminishing returns to scale. This feature of the model implies that capital accumulation cannot be a source of sustained growth. To resolve this issue, it was assumed that the accumulation of capital has a positive externality. For example, the AK model of growth in Romer (2006) assumes that the investment in capital has a positive externality. Firms face a constant returns to scale production function when making their investment decisions in capital. However, the accumulation of capital increases the stock of knowledge, which implies an increasing returns to scale production function for the whole economy. Therefore, the private incentives to invest differ from the social ones. Due to this externality growth is self-sustaining.

Romer (1986) shows that the existence of an externality due to knowledge accumulation is a necessary condition for the existence of a self-sustaining growth rate. This externality implies a difference between private returns to scale and aggregate returns to scale. For example, consider an economy that consists of a final good sector, which is produced by using knowledge and an intermediate input. Knowledge is accumulated over time and is obtained from past inventions. The return on investment in the intermediate sector is constant; however, due

[1] Examples for this type of growth models are the Solow model and the Ramsey model.

to process of knowledge accumulation, the investment in the intermediate sector exhibits a positive externality. Again, due to this externality, the economy grows at a constant rate. The two types of endogenous growth mechanisms I discuss exhibit an externality from knowledge accumulation.

4.1.1 Increased Specialization

The first type of growth model builds on the idea of productivity gains from increased specialization. Dating back to Adam Smith's idea of the pin factory, the growth process is modelled as an increase in the number of intermediate inputs available. A continuum of intermediates exists in an economy and the more varieties available, the more productive the economy becomes due to increased specialization. For example, let an economy produce one final good which is assembled by a variety of intermediate inputs using the CES function

$$Y = \left(\int_0^{n_t} x_i^\alpha di \right)^{1/\alpha} \tag{4.1}$$

for $\alpha \in (0,1)$. Each of the varieties exhibits decreasing returns to scale. If I assume that n varieties exist and each variety x_i is used in the same amount then the above equation simplifies to

$$Y = n^{(1-\alpha)/\alpha} X, \tag{4.2}$$

where $X = nx$ is the aggregate amount of inputs used. If the whole production function is considered, the production function exhibits increasing returns to scale, whereas the aggregate inputs exhibit constant returns to scale. Therefore, an increase in the number of varieties has a positive external effect by making the production process more efficient.

Grossman and Helpman (1991a) model the growth process as an increase in the number of varieties. The economy has an infinitively lived representative household. The household decides to spread optimally its expenditures over time and in each period over the available varieties. The per-period preferences take a similar functional form to equation (4.1). In this set-up, instead of productivity gains in the economy, consumers experience a gain in utility as more varieties become available. The economy is endowed with labour L only. Each variety is produced by one firm that, prior to entering the production stage, has to invent a blueprint for a new variety.[2] Accordingly, the firms face a two stage problem. Firstly, they have to invest in R&D to invent a new variety. Once a new blueprint is discovered, the firms receive a patent which does not expire. Secondly, the firms have to market the newly invented variety. The incentive to invest in a new variety is the net-present monopoly profits. In order to develop a new blueprint in the first stage, the firms have to hire labour for research, which is used in combination with the existing stock of knowledge in the economy. The stock of knowledge is assumed to reduce the costs of future discoveries and evolves proportionally to the number of varieties invented. Therefore, the invention of a variety has the externality of reducing the costs of future inventions. This externality drives the growth process in this model because researchers are able to use past discoveries, developing new varieties at lower costs. For example, a mobile phone could not be invented without the invention of the rechargeable battery. If the battery had not been invented before the mobile phone, then the invention of the latter would be more costly.

The trade-off the economy faces is between current consumption and future consumption possibilities. On the one hand, the more labour is allocated towards the production of the varieties, the higher is the output in a period and thus consumption is higher. On the other hand, the more labour is allocated in R&D, the more varieties are invented and thus the more productive the economy becomes, which implies a higher output in the future periods. The resulting growth rate in the economy is given by

$$g = (1-\alpha)\frac{L}{a} - \alpha\rho. \tag{4.3}$$

The aspect of this growth rate important in this thesis is the growth rate's depen-

[2] It is possible to have a different institutional set-up, for example where a research firm sells the blueprint. However, to make the exposition in this section simple, I treat both firms as one. For a more thorough discussion, see Grossman and Helpman (1991a).

dency on the endowment of labour in the economy, which is denoted by L. The larger the labour endowment, the higher is the growth rate. The reason is that with a larger labour endowment, the market size expands and thus can sustain a larger number of varieties in each period. Therefore, a larger economy has a larger stock of knowledge, which implies a higher number of new entrants and thus growth. Further, the more productive an economy is in doing research, a lower a, the higher is the growth rate. A greater impatience of consumers, higher ρ, implies a lower growth rate.

In Romer (1990) the growth process is similar to the one in Grossman and Helpman (1991a). However, the author shows that human capital is the important driver of growth. The set-up is as follows. The economy is endowed with labour and human capital. The economy comprises two sectors: a final good sector and an intermediate input sector. The final good sector uses labour, human capital and a continuum of intermediate inputs to produce the final output. The intermediate sector is characterized by a continuum of varieties. Each variety is produced by using capital, which is forgone consumption. A variety has to be invented, using human capital and the stock of knowledge, before it can be produced. As in Grossman and Helpman (1991a), the stock of knowledge depends on the number of varieties already invented.

Romer (1990) shows that a unique steady state growth rate exists, which is

$$g = \frac{\delta H - \Lambda\rho}{\sigma\Lambda + 1}. \tag{4.4}$$

Although the economy is endowed with two factors, the growth rate depends on human capital H only.[3] The reason is that human capital faces a trade-off between working in either the final good production or research. In contrast, labour is directly employed in final good production only and thus cannot be allocated towards a different usage. A change in either endowment has the following effect. If the labour endowment in the economy increases, the intermediate sector

[3] δ,σ and Λ are parameters of the model.

becomes more profitable as the final good sector expands, which increases the demand for intermediates. At the same time, a higher profitability in the intermediate sector implies a higher demand for research and thus an increase in the return to human capital in the research sector as well. The increase in the profitability in the intermediate sector and the increase in the research costs cancel each other out and thus an increase in labour has no effect on the growth rate. If the endowment of human capital in the economy increases, more human capital can be employed in research without diminishing the current output. Thus growth is higher.

4.1.2 Quality Improvements

The second type of growth model builds on the idea of quality improvements of an existing type of product. In an industry, products are subject to constant improvements. With an improvement in its product a firm is able to gain a larger share of the market. In an extreme case, this may even render the old product useless. For example, the DVD gradually phases the video cassette out of the market. In the literature I focus on, quality improvements are modelled as discrete jumps, as depicted in figure 4.1.[4] Firms know the existing quality, for example by reverse engineering, and are able to improve it. In this sense, the development of a better quality has an externality to the market, as it provides the base for future research. An example of a production function is

$$Y_t = \int_{i=1}^{n} q_{ti} x_{ti} di, \tag{4.5}$$

where q_{ti} denotes the quality of variety i at time t and x_{ti} is the output of variety i. The number of varieties n is fixed. With each quality improvement, ceteris paribus, the output Y increases. The incentive for firms to invest in quality is that they gain a larger share of the market and thus increase their profits. For example, if the old quality exits the market, the inventor becomes sole producer of the good. The monopoly profits earned in this case provide an incentive for

[4]The figure is reproduced from Barro and i Martin (2004) and Grossman and Helpman (1991a).

continuous investment in a higher quality.

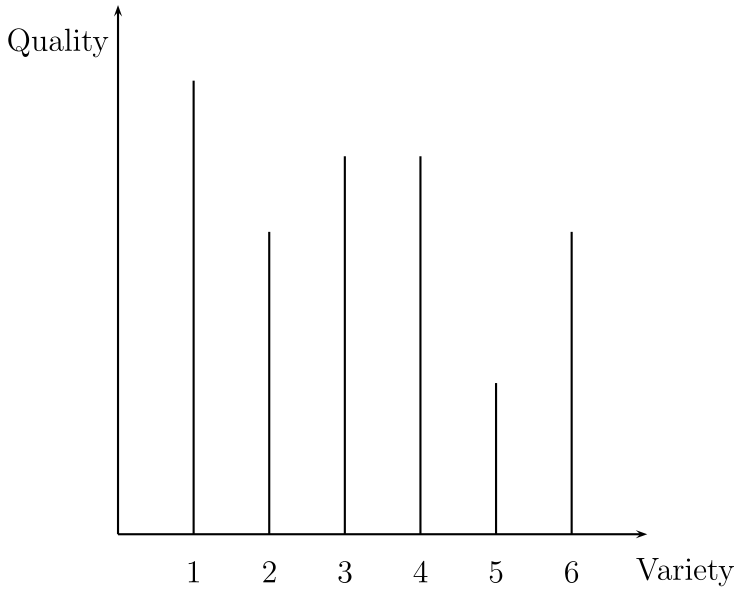

Figure 4.1: Quality Improvements

In Grossman and Helpman (1991c), consumers value the quality of a variety. The per-period utility is similar to the functional form in (4.5). The economy is endowed with labour L, which is used in final good production and research. The number of varieties is fixed. If the quality is improved, the state-of-the-art producer sells the good at the limit price, which is the price where the quality adjusted price of the new and old quality are the same and the consumer is indifferent to the difference between the goods.[5] Due to limit pricing, the state-of-the-art producer becomes the sole producer of the variety. The success in research is stochastic and depends on the size of the investment. It is assumed that the higher the investment in research, the higher the probability of success. The growth rate in the economy is

$$g = \log \lambda \left(\frac{(1 - 1/\lambda)L}{a} - \frac{\rho}{\lambda} \right). \tag{4.6}$$

[5]If the limit price is above the profit maximizing price, the state of the art producer sets the profit maximizing price.

The growth rate depends on the size of the endowments of labour L.[6] The reason, as before, is the trade-off to allocate labour to produce a higher current consumption or to research in order to increase future consumption possibilities. The higher the labour endowment, the more labour is allocated towards research without diminishing current output. A higher absolute employment in research drives growth.

Aghion and Howitt (1992) explicitly model the effect of creative destruction introduced by Schumpeter (1947). The idea of creative destruction is that the prospect of monopoly rents provides an incentive to invest, destroying, however, the business of an existing producer. They consider an economy which is endowed with labour and that produces a final output with a stock of technology and an intermediate input. The intermediate input is manufactured by a monopolist, using labour only. In order to become the monopoly producer of the intermediate, a firm must improve the existing technology. The monopoly profits give firms an incentive to invest. Similar to Grossman and Helpman (1991c), success in research is stochastic; however, the higher the investment, the greater is the reduction in time to the next discovery. Therefore, a higher investment reduces the time of being the monopolist, but increases the chances of becoming the next monopolist. This is the process of creative destruction, where destroying the rents of the existing producers provides the incentive to invest. The growth rate is

$$g = \lambda \varphi(\hat{n}) \ln \gamma, \tag{4.7}$$

where $\hat{n} \equiv \hat{n}(L)$ is the employment in research, which is a function of the labour endowment. Again, my main interest is in the way the factor endowment influences the growth rate: the higher the factor endowment, the higher is the growth rate. The reason is that labour is allocated to research and the production of the intermediate good. The higher the labour endowment, the more labour can be allocated to research which promotes growth.

[6] λ is the step size of a new quality and ρ the private discount rate.

4.1.3 Returns to Scale and Growth

The previously discussed literature return to scale in innovation is non-decreasing: innovation is state dependent. The state dependency of innovation refers to the knowledge spillovers from past innovations to current research costs. For this reason, research costs are not increasing and a steady state with a constant labour force can be found. A particular feature, as pointed out by Kortum (1993), is the proportionality of the stock of knowledge to the growth rate in productivity. This is not in line with the empirical observation that R&D expenditures increase whereas the number of patent grants is constant. Therefore, Eaton and Kortum (1999) develop a semi-endogenous growth model which exhibits decreasing returns to scale in research. A steady state with a constant growth rate can only be achieved if the number of researchers increases. The growth rate does depend on the growth of the labour force, not the absolute labour endowment. The work in this part of the thesis uses a endogenous growth model to generate the effect of offshoring on the growth rate. The reason for this assumption is that otherwise, by definition, offshoring has no impact on the growth rate.

4.1.4 Economic Integration and Growth

Rivera-Batiz and Romer (1991) show that the effect of economic integration on growth depends on the set-up of the theoretical model. They develop two models, both with increasing varieties and with a set-up similar to Romer (1990). The difference between the two models is the production function of varieties. In what they call the knowledge driven model, varieties are invented using the existing stock of knowledge. The second specification is what they call the lab-equipment specification. In this model, new varieties are invented using a capital good, which is modelled as forgone consumption.

Rivera-Batiz and Romer (1991) conduct three thought experiments on how economic integration affects the growth of an economy. Firstly, they consider trade in capital goods in the knowledge driven model, with flows of knowledge prohibited. They show that output per period increases. However, this leaves growth unaffected. The reason is that trade does not affect the allocation of human capital to research, which leaves the invention of new varieties unaffected, as seen by (4.1). Secondly, they consider the impact of international knowledge flows on growth in the knowledge driven specification. If trade in capital goods is permitted, knowledge becoming tradable increases the growth rate.[7] This is because, if the stock of knowledge increases, research becomes more efficient and thus more human capital is allocated towards the invention of knowledge. Thirdly, in the lab-equipment specification, the flow of capital goods increases growth. The reason is that, with trade in goods, the profits in the intermediate sector increase, which gives an incentive to invest more in new varieties. In this instance, they show that it is not only international knowledge flows that matter for growth but also trade in goods. The lesson learned from their argument is that knowledge flows and trade flows as well can influence growth, depending on the structure of the economy.

4.1.5 The Case of Divergence in the Literature

In chapter 8, Grossman and Helpman (1991b) develop a dynamic factor proportion model. The authors assume two countries, each endowed with skilled and unskilled labour. The countries differ in their relative endowments. Two final good sectors exist, where one sector produces a traditional good, while the other sector produces a high-tech good. In the latter sector R&D takes place, which is modelled as increasing varieties. They show that, if the endowments are not too dissimilar, an integrated equilibrium exists at which both countries grow at the same rate. Factor prices are equalized in this equilibrium. However, if the endowments are sufficiently dissimilar, factor prices do not equalize and it is possible that the country with the relatively higher endowment of unskilled labour eventually stops to invest in R&D and specializes in the production of the traditional

[7]The size of the impact on the growth rate depends on the number of overlapping varieties in both countries.

good.[8] In the extreme case, the production of the high-tech good in one country eventually ceases and the country becomes fully specialized in the production of the traditional good.

4.2 Offshoring

Offshoring has recently sparked a lot of research. It is understood as the transfer of production stages to a different country.[9] Jones and Kierzkowski (1990) conceptualize the production process as production blocks, which are linked by services to coordinate the production. Those services allow the production process to be fragmented. With the improvement of the service links, production gets more fragmented and more production blocks are moved abroad. In the remainder, I will discuss their work in more detail and introduce the concept of "trade in tasks" by Grossman and Rossi-Hansberg (2008).

In a diagrammatical approach, Jones and Kierzkowski (1990) show that international fragmentation allows economies to organize their production process more efficiently. Their way of conceptualizing the production process is to assume that the production of an output is fragmented in production blocks which are linked via services. For example, a car is produced by combining different inputs. In particular, the car is designed in Germany, but produced in the US. The authors argue that the improvements in service links, for instance communication technologies, make a more fragmented production process possible by reducing costs of the linkage. In the above example of a car, costs are reduced by emailing instead of posting the blueprint as emailing connects engineers and practitioner more directly. Therefore, changes to the blueprint can be made more quickly, which reduces costs. The theoretical argument is illustrated in figure 4.2.[10] Let the cost of a domestic production block be represented by line H, where the slope represents the marginal costs of production. The vertical intercept implies fixed

[8] The country still produces the varieties that are already invented.

[9] See, for example, Blinder (2006).

[10] The figure corresponds to figure 3.5 in Jones and Kierzkowski (1990)

costs. Further, let the cost of a production block located abroad be represented by line M. The costs of the service link shifts both cost lines upwards. It is assumed that the service link has higher fixed cost if it is located abroad. The point e denotes the output at which the costs of domestic production and foreign production are equal. A firm would minimize costs by locating the production abroad if output is above e, which is cost minimizing. Therefore, a country that has an internationally fragmented production process gains from offshoring because of reduced costs. If the service costs reduce, the M' line shifts down, reducing the cut-off output e. Thus a fall in service costs makes a fragmented production block more likely. Jones and Kierzkowski (1998) remark that this mechanism is like technological progress because international fragmentation of the production process is similar to switching to a more efficient production technology.

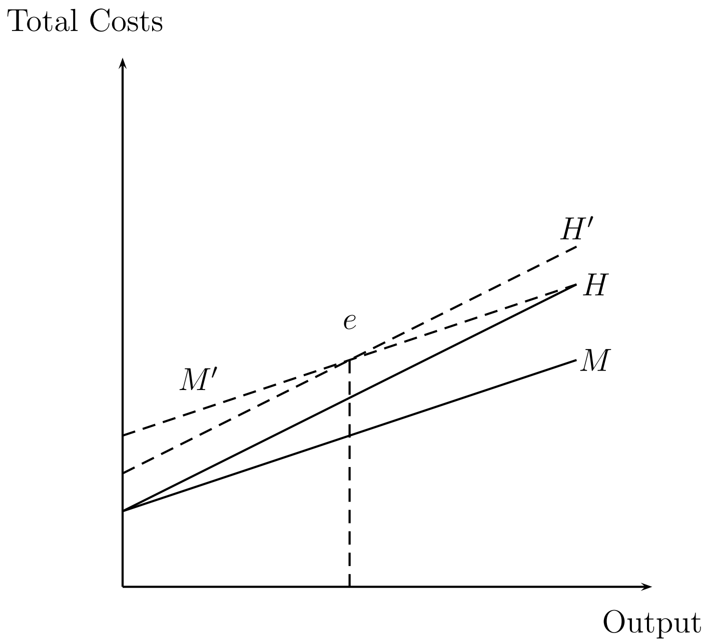

Figure 4.2: Costs and International Fragmentation

Jones and Kierzkowski (1990) also provide examples of how economies can benefit in terms of welfare by specializing in producing the input in which the economy has a comparative advantage. For instance, if a country has a Ricardian comparative advantage in the production of a particular intermediate stage, it can specialize in the production of this stage. In specializing, the usual gains from specialization apply and the economy is better off. In a formal approach, Francois (1990a), (1990b) and (1990c) shows that producer services play an important role in an increased division of labour and efficiency gains due to specialization.

Grossman and Rossi-Hansberg (2008) develop a formal theory of offshoring. In their paper, the production process of the finished good is divided up into a continuum of tasks that have to be performed. For example, to produce one car, a lot of jobs have to be performed. Not only must all parts be assembled but other processes, such as accounting or marketing, contribute to the final product.[11] In general, they assume that the tasks can be performed anywhere in the world. However, if performed abroad, each task has the additional cost of delivering it to the firm. Those trade costs differ for each task. Therefore, some tasks are less costly to offshore than others, which results in some tasks being offshored while others are produced domestically. The authors are interested in the effect of offshoring on wages, which they show in a simple Heckscher-Ohlin type framework. They find three effects of offshoring on wages, which I briefly discuss below.

The set-up in Grossman and Rossi-Hansberg (2008) is as follows. There are two final goods which are produced using two factors of production: skilled and unskilled labour. Each final good sector is perfectly competitive. The final sectors may differ in their factor intensities. Both skilled and unskilled labour have to perform a continuum of tasks to produce one unit of a final good. Grossman and Rossi-Hansberg (2008) consider offshoring for both factors of production. However, in my discussion I focus on offshoring of the unskilled tasks only. Tasks differ in their trade costs. Firms have an incentive to offshore if the potential for cost savings exists. Grossman and Rossi-Hansberg (2008) show that offshoring has three effects on the wage of the unskilled workers. Firstly, there is a productivity effect. With offshoring, firms are able to mix domestic labour with foreign labour, which is cheaper. Due to this mix, the effective costs of domestic labour

[11] Of course, the parts of a car have to be produced as well.

decline. This is like Hicks-neutral technological progress. The effect on the wage of unskilled labour is that it increases. Secondly, there is a labour supply effect. Given the nature of offshoring, tasks are moved abroad. The labour previously employed in performing those tasks is freed and can be reallocated within the economy. Thus the effective endowment of the economy increases. The effect on the wage of unskilled labour is that it decreases. Thirdly, there is a relative-price effect. Due to offshoring, firms are able to reduce their costs. Thus, prices must fall. If, for example, one sector is unskilled labour intensive, the price reduces further, which changes the terms-of-trade. This effect decreases the wage of unskilled labour.

Olney (2009) shows empirically that offshoring in general has a positive impact on the wages of workers in the US.[12] Using a similar theoretical model to Grossman and Rossi-Hansberg (2008), the author shows that offshoring has a positive impact on the wage of workers due to the productivity effect. The empirical data supports the finding of the theoretical model, except for the 8th percentile of the income distribution. Distinguishing between offshoring to developed and less developed countries, the former has a negative impact whereas the latter has a positive impact on wages.

Baldwin and Robert-Nicoud (2007) use the idea of trade in tasks in Heckscher-Ohlin-Samuelson framework and show the effect of offshoring on the economy. The authors develop a two economy model with two final outputs and two factors of production. One of the countries is assumed to have a technological disadvantage in the sense that more inputs are needed to contribute one unit to the final production. If a task is offshored, the technology is transferred as well. The authors show that this type of offshoring is like shadow migration: firms in the technologically advanced country use foreign factors of production in combination with their technology, which is like increasing the effective endowment of the advanced country. They show that a Rybczynski theorem of offshoring

[12] The author considers immigration as well, which I disregard in my discussion.

exists. The sector that uses the offshored factor relatively more intensively increases its output, whereas the other sector contracts. However, they show that if the relative factor intensities are similar in both sectors, a set exists where both sectors increase their output. This is called the anti-Rybczynski result. Similarly, they show that a Stolper-Samuelson Theorem of offshoring exists. The return to the factor that is relativity more used will increase if the costs savings due to offshoring are large in that sector. However, if the ratio of cost savings of the two sectors is between the relative capital and relative labour intensity, both returns to the factor increase. This is called the anti-Stolper-Samuelson result.

4.3 A simple Model

In this section, I develop a highly stylized model to introduce the underlying argument of the following chapters.[13] As I summarize in table 4.1, the growth rates in the previously discussed models depend on the factor endowments of the economy. The main idea is that offshoring might free resources within an economy and allow its reallocation such that the growth rate increases. This argument very much follows Jones and Kierzkowski (1990) and Jones and Kierzkowski (1998) in the sense that offshoring, like trade in final goods, allows for a more efficient allocation of labour. In this sense, offshoring is like an increase in the effective endowment of an economy.

In this section, the growth process is modelled as learning-by-doing. I assume a small open economy that produces one final output using an intermediate input X_t, capital K_t and the stock of knowledge A_t. The economy is endowed with labour only. The time horizon is infinite with $t \in [T, \infty)$. The final output is produced in a perfectly competitive market. Every producer faces the production function

$$Y_t = K_t^{\alpha} \left(A_t X_t\right)^{1-\alpha}, \tag{4.8}$$

[13]The basic set-up largely follows the model in the section on learning-by-doing in Romer (2006) chapter 3.4

Paper	Growth Rate	Endowment(s)
Aghion and Howitt (1998)	$\lambda\varphi(\hat{n})\ln\gamma$ where $\hat{n} \equiv \hat{n}(L)$	L
Grossman and Helpman (1991a)	$(1-\alpha)\frac{L}{a} - \alpha\rho$	L
Romer (1990)	$\frac{\delta H - \Lambda\rho}{\sigma\Lambda + 1}$	L, H

L is labour and H is skilled labour

Table 4.1: The Growth Rates

taking A_t as given. Capital accumulation has a learning externality. I assume that the stock of knowledge depends positively on the stock of capital. The idea is that previous experience increases the working knowledge in the economy, which makes the production of a final good more efficient. However, firms take the stock of capital as given and thus do not take it into account when making the investment decision. Accordingly, there is a difference between the private returns to scale and the social returns to scale in the final good production, which is a necessary condition for endogenous growth. Firms face a constant returns to scale production function, whereas the social production function, taking into account the learning externality, exhibits increasing returns to scale. For simplicity, I assume that the stock of knowledge is equal to the stock of capital. Romer (2006) considers different exponential forms of the knowledge accumulation which are of interest on their own, but do not contribute to my argument. Thus

$$A_t = K_t. \tag{4.9}$$

By substituting the function of knowledge accumulation (4.9) into the production function, I obtain a social production function

$$Y_t = X_t^{1-\alpha} K_t. \tag{4.10}$$

I assume the savings rate s to be constant. The rate of capital accumulation is $\dot{K} = sY_t$, where a dot denotes a change in the variable. Substituting the expression for output (4.10) into the rate of capital accumulation yields

$$\dot{K}_t = sX_t^{1-\alpha} K_t. \tag{4.11}$$

Now I can derive the growth rate of output, which, in this set-up, is proportional to the rate of capital accumulation. The growth rate is

$$g_Y = g_K = sX^{1-\alpha}. \tag{4.12}$$

As I show later, the output in the intermediate sector remains constant over time. The important aspect of this growth rate is that it depends on the output of the intermediate good X. The more an economy can produce of the intermediate, the higher is the absolute saving. Because the stock of knowledge depends by definition on the absolute accumulation of the stock of capital, an increase in output results in a higher growth rate.

Having discussed the dependence of the growth rate on the level of the intermediate produced, I turn to the discussion of the intermediate sector. The intermediate input is produced by two tasks in the sub-production function

$$X_t = L_1^{\beta}(aL_2)^{1-\beta}, \tag{4.13}$$

where $a > 0$ is a unit input requirement. Each task is performed by labour. I assume that only the tasks are tradeable. The assumed structure of the intermediate production is similar to a Ricardian framework. I assume that $p_1 < p_1^*$ and $p_2 > p_2^*$ in all periods. Furthermore, I assume that p_j/p_j^* for $j = 1, 2$ is constant over time as well. According to the law of comparative advantage, the domestic economy specializes in the production of task one and imports task two. The argument is demonstrated graphically in figure 4.3. The autarky cost line is denoted by $p^a \equiv p_2/p_1$. The isoquant X^a indicates the output level of the intermediate. The optimal input combination of the two tasks is found at the tangency of the isoquant with the cost line denoted by p^a. The further an isoquant is from the origin, the higher is the output level. The allocation of labour to the production of the tasks is given by L_1 and L_2, with $L = L_1 + L_2$ in equilibrium. If offshoring is possible, the economy faces the worldwide relative price $p^* \equiv p_2^*/p_1^*$. The economy specializes in the production of task 1 and thus all labour is allocated to its production. The optimal output is given by the isoquant X^*. Therefore, the output of the intermediate input increases due to offshoring.

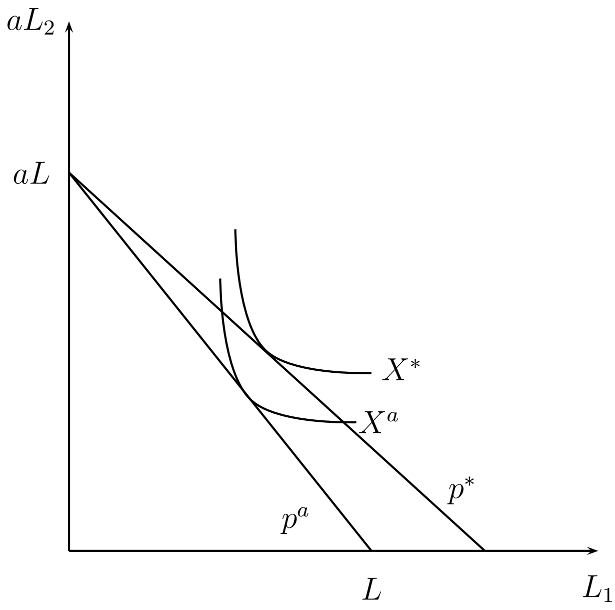

Figure 4.3: Gains from Offshoring

Given that the output in the intermediate sector increases, the growth rate in the economy also increases, as in (4.11). The reason is that allowing for trade in this framework leads to gains in efficiency; labour is allocated to the sector in which the economy has an comparative advantage. Due to these efficiency gains, output increases, which implies a higher absolute capital accumulation. Although offshoring induces a one time efficiency gain due to increased specialization, the gain is not just static but dynamic in that it increases the stock of knowledge. In the next chapters, I will investigate the efficiency gains in more detail and track their effect on growth.

4.4 Discussion

In this chapter, I introduced the main argument of this part of the thesis. I showed that the growth rate of an economy depends on the factor endowment of the economy. I further showed that due to offshoring, factors of production can be allocated more efficiently to production. This efficiency gain increases the growth rate of an economy. In the coming chapters, I will show that this argument holds in a more general set-up and can be generalized in a model with two factors of production.

Chapter 5

Growth and Offshoring in a Small, Open Economy

5.1 Introduction

Through offshoring, the possibilities for a country to specialize further increase beyond the gains from specialization in final products. Economists know that increased specialization generally improves welfare. In this paper, I look at how countries can gain dynamically from increased specialization via offshoring. I show that offshoring influences the allocation of labour between direct production and research, which then affects growth.

Little work has been done so far on how offshoring affects the future prospects of an economy. The current literature is largely confined to the analysis of the static effects of offshoring, such as its impact on wages of skilled and unskilled workers. It is, however, important to investigate what influence offshoring has on production possibilities in the long-term. For example, if offshoring makes it possible for a country to invest more in future technologies, the country's prospects improve.

The framework I develop is of a small, open economy. A single final output is manufactured using an intermediate input and the latest available technology.

Growth is driven by vertical improvements of the existing technology. The growth mechanism in the economy follows Aghion and Howitt (1992), where becoming a monopoly producer of the intermediate input gives the incentive to invest in technological improvement.

Offshoring takes place in the intermediate sector and is thought of as trade in tasks, a concept introduced by Grossman and Rossi-Hansberg (2008). For one unit of the final good to be produced, labour has to complete a continuum of tasks. Offshoring follows a cost-savings motive: tasks are offshored if they are cheaper abroad. Not all tasks, however, are equally offshorable. For example, a janitor's task cannot be offshored, as the task needs to be performed in close proximity to the production facility. An accounting task might be easier to offshore as communication links between countries have improved.

Grossman and Rossi-Hansberg (2008) further show that countries that offshore are subject to three effects: a productivity effect, a labour-supply effect and a relative-price effect. In a Heckscher-Ohlin-Samuelson (HOS) setting, they show that the productivity effect increases the wages of labour whose tasks are offshored, whereas the labour-supply and relative-price effects decrease wages. Baldwin and Robert-Nicoud (2007) deploy the notion of trade in tasks in a HOS setting and show that the traditional theorems are fairly robust with respect to the effect of offshoring.[1] They further show that the effective world endowment of labour increases, which has a positive impact on world output.

In order to investigate the relationship between offshoring and growth, it is important to differentiate between a country that offshores the tasks and a country that receives the offshored employment. The idea behind offshoring is that firms are able to hire foreign labour to produce some tasks for them. Firms import the finished tasks and use them in the production of the final output. A

[1]By the traditional theorems, I refer to the Stolper-Samuelson theorem, Rybczynski theorem, factor-price equalization theorem and the Heckscher-Ohlin theorem.

receiving economy produces the tasks for exporting to the rest of the world. In the offshoring country, labour is released for other activities, specifically research, whereas in the receiving country, more labour is drawn into the export sector. For an offshoring country, it is likely that growth increases as labour is moved towards an innovative sector. For a receiving country, labour is diverted from research into producing the exported tasks, which harms growth. However, if offshoring is also accompanied by factors such as technological spillovers or incentives to get better education, growth prospects for the receiving economy might improve. Subsequently, I analyze the implications both for a country that offshores and for a country that exports the offshored tasks.

In an offshoring country, labour is affected by offshoring in two ways. Firstly, unit costs fall because offshoring exhibits characteristics of technological progress. This is because the combination of low-cost labour from abroad and domestic higher cost labour decreases the effective costs of domestic labour. Secondly, through offshoring the effective labour force is increased. Offshoring reduces the number of tasks that are performed by domestic labour. Despite an expansion of the production sector due to cost savings, some workers get employed in the research sector as the average return to investment in innovation increases. This labour-supply effect is what drives a higher growth rate in the economy. I show that if the offshoring country has a higher growth in wages than the rest of the world, it eventually specializes in research. If wages in the small economy grow at a slower rate than in the rest of the world, offshoring will eventually cease to take place as the cost savings potential decreases.

In an empirical study by Daveri and Jona-Lasinio (2008), the authors find mixed results for the effect of offshoring on productivity growth in Italian manufacturing. Their results, however, are sensitive to the measure of offshoring used. In another empirical study, Egger and Egger (2006) show that in the long-term, productivity of low-skilled labour in the EU increases with offshoring, which can be interpreted as evidence supporting the productivity effect of offshoring.

In an economy that exports the offshored tasks, labour is diverted towards the production of those tasks. The diversion therefore results in declining investment in the exporting country's research. The exporting economy specializes in production of tasks if wages grow faster in the rest of the world than domestically. The reason is that the return to research is too low to attract workers from the production sector where they earn a higher wage.

These results suggest that, for a small country that exports tasks, offshoring reduces welfare. However, this result depends on the assumptions made on knowledge spillovers. Amiti and Konings (2007) have recently shown for Indonesia that spillovers of imports are important for the growth of a country that is less developed. In a very general set-up, they show that imported inputs increase growth. In another paper, Halpern, Koren, and Szeidl (2005) show for Hungary that offshoring's positive effect on growth is due to a higher quality of imported goods compared to domestic inputs.

Rodriguez-Clare (2007) develops a model of growth and trade in tasks. He uses trade in tasks in a quality-ladder model with Ricardian comparative advantage in final good production. He shows that a country that offshores gains from trade, whereas a country that exports the tasks reduces its innovative effort and therefore suffers from offshoring. These conclusions are similar to those of my work. However, I show that although the final good is homogeneous, a country specializes according to its comparative advantage in either research or tasks.

5.2 The Model

I start the discussion of offshoring and growth with the country that offshores tasks. In the next section I analyze an economy that receives the offshored tasks. The set-up of the both economies are the same. In each case the economy is assumed to be small in relation to the rest of the world, therefore taking the worldwide prices as given.

The small economy has three sectors. Firstly, a sector that assembles a final good from an intermediate input. Secondly, an intermediate sector that produces the intermediate from a continuum of tasks, which can be offshored. Thirdly, a research sector where the innovation takes place. I discuss each sector in detail before deriving the equilibrium conditions.

5.2.1 Households

There exists a continuum of infinitely-lived consumers who share the same preferences. The consumers are assumed to care only about consumption over their lifetimes. In every period, marginal utility is constant. The utility function takes the form

$$U = \int_0^\infty e^{-r\kappa} c_\kappa d\kappa, \tag{5.1}$$

where r is the discount factor, which is equal to the interest rate in the economy due to constant marginal utility of consumption. Consumption is measured over a period of time κ.

The sole primary factor of production is called labour L. The economy has a fixed endowment of labour at any given level of technology. In equilibrium, labour has to be fully employed which implies that

$$L = L_{x_t}^D + n_t, \tag{5.2}$$

where $L_{x_t}^D$ is the employment in the intermediate sector and n_t is the employment in research.

5.2.2 Intermediate Production

The intermediate input is produced by using a continuum of tasks some of which can be offshored. I follow the notion of Grossman and Rossi-Hansberg (2008) who formalize trade in tasks. By looking at the production of a good in terms of tasks, the production chain is sliced up into the jobs that have to be completed to finish a good. This includes, for example, assembly as well as marketing or accounting. Each task has a labour input requirement a_x that is assumed to be the same for all tasks. I further assume that the measure of the tasks is unity. Not all tasks have to be executed by domestic labour as some may be offshored. However, the cost of offshoring different tasks varies. Some tasks, for instance, need to be performed in proximity to the domestic production facility whereas other tasks can be located somewhere else at low costs. Accordingly, it would be very costly - even prohibitively costly - to offshore some tasks. For example, accounting might be easily offshored whereas a janitor's job simply cannot be offshored. Further, the costs of offshoring are not necessarily correlated to skill intensity. This is formalized by assuming a task specific transport cost $\tau(j) > 1$, where j indicates the task. Let $\tau(j)$ be a continuous function with tasks ordered in a non-decreasing way, which implies $\tau'(j) > 0$. For simplicity, I assume that offshored tasks have the same labour input requirements a_x as domestic tasks. Thus the benefit of offshoring arises, not from saving labour, but from lower-cost foreign labour.

Offshoring follows a cost savings motive. All tasks that can be imported cheaper from abroad are offshored. In this way, a domestic firm can utilize cheaper foreign labour to reduce its own costs of production. I assume that the wage in the rest of the world is lower than the domestic wage, $w^* < w$, and that each task is produced in a perfectly competitive environment. This implies that neither a worker performing a task nor the firm for which the task is done has any market power. Therefore an intermediate producer offshores if the import price of a task is not larger than the price of domestic production of the task

$$w \geq w^* \tau(j) \tag{5.3}$$

where w is the domestic wage and asterisk indicates the rest of the world. As long as domestic labour is more expensive in the production of task j than the import price of a task, the task is offshored. A marginal task J exists if the domestic labour costs are equal to the import price of the task. Given that the transport costs increase in j, there might exist a task for which the economy is indifferent between domestic production or offshoring. I assume that the marginal task is offshored.

The marginal task is endogenously determined in equation (5.3). In the following discussion I assume that a marginal task exists, such that equation (5.3) holds with equality. However, I will show that an interior solution, $J \in (0,1)$, for the marginal tasks does not always exist.

With the existence of an interior solution, the intermediate producer has to pay domestic labour for the tasks it performs and pay the import price of the tasks that are offshored. The unit cost of an intermediate producer is

$$c_m = w(1-J)a_x + w^* a_x \int_0^J \tau(j)dj, \tag{5.4}$$

where $1-J$ is the measure of the tasks performed domestically. Using the cut-off in (5.3), which holds with equality, I rewrite the unit cost function as

$$c_m = wa_x\Omega(J) \tag{5.5}$$

where $\Omega(J) \equiv 1 - J + [\int_0^J \tau(j)dj/\tau(J)]$ is less than one. $\Omega(J)$ is interpreted as the cost savings potential.[2] The cost-savings potential is illustrated in figure 5.1. In the absence of the possibility to offshore, the intermediate producer has to spend wa_x for every task, which is the horizontal domestic-supply line at $a_x w$. The marginal costs are found by integrating over all tasks, which yields the area consisting of A,B and C. If offshoring is possible, the cost of importing task j is $w^* a_x \tau(j)$, shown as the upward-sloping import-cost line. For simplicity, I assume linear transport costs. As long as the import costs are below the costs of domestic production, the tasks are offshored. Accordingly, the marginal task J is at the intersection of the import-cost line and the domestic-supply line. Due to offshoring, the unit costs reduce to the areas A and B, which implies that C

[2]Grossman and Rossi-Hansberg (2008) call this the productivity effect of offshoring. However, they look at changes in $\Omega(J)$ as J changes.

represents the cost savings, $1 - \Omega(J)$. If, for example, the transport costs of all tasks fall proportionally, the import cost line shifts downwards. Therefore, the marginal task shifts to the right and the cost savings C increases. If the marginal task is $J = 1$, all tasks are offshored.

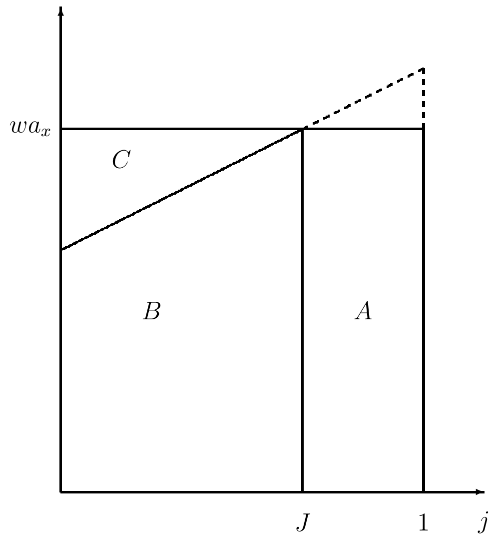

Figure 5.1: Cost Savings Potential

5.2.3 Research

The monopoly profit accruing to the winning intermediate-goods producer provides an incentive for firms to invest in improving technology. Research is modelled as a stochastic-patent race, where the arrival time of the innovation for each investor is stochastic. A continuum of research firms is entering the race to improve the existing technology. The research firm that is first in making the discovery receives an infinity-lived patent. This patent enables the research firm to drive out the existing intermediate-goods producer and become the new incumbent producer. All other research firms discard their current research. However, the patent does not protect the new incumbent from firms improving the new technology. For example, research firms could reverse engineer the new technology and then improve upon it.

Research firms are able to invest in innovation by hiring labour at the prevailing wage rate in order to carry out the research for them. I assume that research follows a Poisson process with arrival rate λn_t, where λ is the productivity of research. The Poisson arrival rate gives the average time an investor has to spend in the research lab. The production function of the research sector, which is the Poisson arrival rate, is homogeneous of degree one. Therefore, I can restrict the discussion to a representative firm. The assumed stochastic process has the feature that the higher the investment in research, the less time elapses until the next discovery is made.

The investment into research follows a trade-off between the expected profits from innovation and the cost of the investment. Let V_{t+1} be the value to a research firm of becoming the new incumbent at $t+1$. A research firm is successful with a probability of λn_t. Therefore, the expected discounted profits are $\lambda n_t V_{t+1}$. On the cost side, a research firm employs labour n_t to carry out research at the current wage w_t. Hence, the investment costs are $w_t n_t$. Firms invest in research until the expected discounted profits equal the investment costs. The investment condition therefore is

$$\lambda V_{t+1} = w_t. \tag{5.6}$$

The intuition for this condition is that the expected value of innovation per unit of research must be equal to the unit cost of investment. If the expected value of innovation per worker is larger than the marginal cost of investment, research firms have an incentive to further invest in research until the marginal benefits equal marginal costs.

How is the value of V_{t+1} determined? The successful innovator of the $(t+1)^{th}$ quality step is guaranteed monopoly profits π_{t+1} until a new technology is invented. A new technology is invented after an average time of λn_t. With a new technology, the flow of profits to the incumbent ends. The expected loss of profit flows to the incumbent is therefore $\lambda n_t V_{t+1}$. Instead of investing in innovation, a research firm could buy a bond of value V_{t+1} on the capital market and receive a rent of rV_{t+1}. A research firm would invest in innovation as long as the return of investment is not smaller than the return of the bond. Thus, the value of the discounted profits is governed by an asset-price equation

$$rV_{t+1} = \pi_{t+1} - \lambda n_{t+1} V_{t+1}. \tag{5.7}$$

This condition constitutes the process of creative destruction. The larger the potential monopoly profits, the more firms invest, with the result of reducing the reward of investment due to an expected shorter time period as incumbent.

Rewriting the asset-price equation (5.7) and substituting it into the entry condition (5.6) results in the no-arbitrage condition

$$w_t = \frac{\lambda \pi_{t+1}}{r + \lambda n_{t+1}}. \tag{5.8}$$

The current wage rate therefore depends on the profits of the next successful innovator and the number of researchers that aim to replace the next innovator.

5.2.4 Final Output

The final output sector is assumed to be perfectly competitive. I assume that the final good is produced using an intermediate input and the latest technology. The intermediate input is provided by whichever firm is able to provide the latest technology. In each period, the production function for the final good is

$$y_t = A_t x_t^{\alpha} \tag{5.9}$$

where $0 < \alpha < 1$ and t denotes the t^{th} innovation. The intermediate input is denoted by x_t and the level of technology is denoted by A_t. With each improvement in the quality of the intermediate good, the level of technology increases by the step size γ.

5.2.5 Equilibrium

In this subsection, I show that a steady-state growth rate exists, defined as a constant growth of all variables. For the economy to be in equilibrium, three conditions must be satisfied. The first equilibrium condition is that the no-arbitrage condition (6.14) must be satisfied. The second equilibrium condition is that a marginal task exists, which implies that equation (5.3) must hold with equality. The third equilibrium condition is that the labour market must clear. Labour in the intermediate sector is used to perform the tasks that are not offshored. The resulting labour demand is

$$L_{x_t}^D = (1 - J)a_x x_t. \tag{5.10}$$

Before I derive the equilibrium research employment, I derive the optimal output of an intermediate producer. The demand for the intermediate is derived from the production function in (5.9), which yields

$$p_t = \alpha A_t x_t^{\alpha-1}. \tag{5.11}$$

The intermediate producer faces a downwards sloping demand curve when maximizing her profits. Accordingly, the incumbent sets an output such that

$$\begin{aligned} x_t &= \arg\max\nolimits_{x_t}[\alpha A_t x_t^\alpha - w_t a_x \Omega(J) x_t] \\ &= \left(\tfrac{w_t a_x \Omega(J)}{\alpha^2 A_t}\right)^{\frac{1}{\alpha-1}} \end{aligned} \tag{5.12}$$

The output of the intermediate depends negatively on the effective wage, $\omega_t \equiv w_t/A_t$ and on the cost savings $\Omega(J)$. Therefore, a higher costs savings potential implies a higher output.

The decision the economy faces in each period is how to allocate labour to research and intermediate production. For example, the more labour is allocated towards research, the higher is the growth rate and the future consumption possibilities; however, the lower is current consumption. Given the optimal behaviour of all agents in the model, an equilibrium is defined by the employment in research. The intuitive explanation is that once research firms make their decisions in hiring labour, labour not employed in research is employed in production and all prices in the economy, especially wages, are set accordingly. I substitute the full employment equation into the no-arbitrage condition and solve for n_t. The equilibrium employment condition in the research sector is

$$\hat{n}_t = \frac{\Theta(J)L - r}{\lambda + \Theta(J)} \tag{5.13}$$

where $\Theta \equiv \gamma\lambda^{\frac{1-\alpha}{\alpha}}[\Omega(J)/(1-J)]$. The equilibrium employment in research depends on the marginal task J. Although a marginal task might exist in every period, the marginal task might change over time. For example, if the domestic wage grows faster than the wage in the rest of the world then, with each innovation, it becomes optimal to offshore to a larger extent and thus J increases over time. In order to determine the optimal J, I have to look at equation (5.3), which determines the marginal task. Rewriting the latter equation in logs and differentiating it with respect to time t, I obtain

$$\tilde{w} - \tilde{w}^* = \tau(\tilde{J})\frac{\partial J}{\partial t} \tag{5.14}$$

where the tilde represents a percentage change.[3] The economy takes the evolution of the wage in the rest of the world, $\tilde{w}^*$, as given. The sign of the derivative is determined by the evolution of the relative wage gap in the small economy to the rest of the world. Accordingly, to find the equilibrium employment in research, I distinguish between three cases (I) divergence in the wage gap, (II) constant wage gap and (III) convergence in the wage gap.

(I) Divergence ($\tilde{w} > \tilde{w}^*$)

Divergence in the wage gap implies that the wage in the domestic economy on average grows faster than the outside world. What is the pattern of offshoring? In the case under consideration, it holds that $\partial J/\partial t > 0$ and therefore the wage gap increases until it becomes sufficiently large that all tasks are offshored. Accordingly, the small economy has a comparative advantage in research which it specializes in.

[3] $\tilde{w}$ and $\tilde{w}^*$ are percentage changes over time and $\tau(\tilde{J})$ represents a percentage change of the transport cost of task J.

It follows that the steady-state employment in research is $\hat{n}$ where

$$\hat{n} = L. \tag{5.15}$$

(II) Constant wage gap ($\tilde{w} = \tilde{w}^*$).

A constant wage gap implies that both the small economy and the rest of the world grow at the same rate. If the wage gap is sufficiently small, the marginal task has an interior solution $J \in (0, 1)$, which remains constant over time. Therefore, the small economy remains incompletely specialized.

It follows that the steady-state employment in research is

$$\hat{n} = \frac{\Theta(J)L - r}{\lambda + \Theta(J)}. \tag{5.16}$$

(III) Convergence ($\tilde{w} < \tilde{w}^*$)

In this case, the wage gap between the small economy and the rest of the world decreases over time. Accordingly, the wage gap closes or even reverses. I postpone the discussion of a reversion of the wage gap to section 5.4, when I analyze a small economy that exports finished tasks. With a closing wage gap, eventually no tasks are offshored as the cost savings incentive vanishes. I will use this as the benchmark case.

It follows that the steady-state employment in research is

$$\hat{n} = \frac{\lambda \gamma^{\frac{1-\alpha}{\alpha}} L - r}{\lambda(1 + \gamma^{\frac{1-\alpha}{\alpha}})}. \tag{5.17}$$

5.3 An Offshoring Economy

In this section, I discuss the growth rate in an economy that offshores tasks. The growth rate is derived for this economy, but I will use the derivation in the next section as well when I discuss an economy that receives the offshored tasks.

5.3.1 Growth

The growth rate is defined as the average change in final output over a period of real time, $g \equiv E(\ln y_{\kappa+1} - \ln y_{\kappa})$. I firstly look at the growth rate assuming a constant wage gap, which implies that the economy is incompletely specialized with $J \in (0, 1)$. Subsequently, I look at an economy that is completely specialized in research.

Growth in the economy is driven by improvements in the productivity of the final output production. From the Poisson arrival rate, I know that the average time period between two innovations is λn. However, λn is the average number of innovations in one period of real time.[4] Each time an innovation is introduced to the market, the technology stock A_t is increased by γ. Accordingly, I can write the log change of output with each innovation as $\ln y_{t+1} - \ln y_t = \ln \gamma$. Further, this increase in output per period occurs $\lambda \hat{n}$ times in a unit-interval of real time. Accordingly, the growth rate is

$$g = \lambda \hat{n} \ln \gamma. \tag{5.18}$$

It follows that growth and employment in research are positively correlated: an economy that allocates more labour towards research in a steady-state has a higher growth rate. This can be understood as follows. The more labour is in the research sector, the shorter is the average period between two innovations. Therefore, the number of innovations in one interval of real time has increased as well. Of course, the employment in research depends on the parameters of the

[4]The equivalence is derived from the Poisson distribution. Intuitively, the unit interval of real time can be divided in sub-segments of length $(\lambda n)^{-1}$. Accordingly there are λn intervals in one unit real time interval.

economy under consideration.

I now turn to the case where the rest of the world has a lower growth rate in wages and I assume that $\tilde{w}^*$ grows at a constant rate. The small economy is completely specialized in research. The output in the intermediate sector increases as w_t^*/A_t decreases over time. This implies that the effective wage paid to foreign workers decreases.[5] Substituting the expression for the output of the intermediate (5.12) into the production function for the final output and taking logs of the resulting expression yields

$$\Delta_t \ln Y_t = \frac{1}{1-\alpha} \ln \gamma - \frac{\alpha}{1-\alpha} \Delta_t \ln w_t^* \tag{5.19}$$

where Δ_t is the difference between two innovations. The expression in (5.19) is larger than zero which implies that the small economy experiences a positive growth. The growth rate of the small economy therefore must take into account the change in the wage of the rest of the world. The small economy experiences growth from innovation as before and, additionally, growth from declining effective import costs. Therefore the growth rate is

$$g = \frac{1}{1-\alpha} \lambda L \ln \gamma - \frac{\alpha}{1-\alpha} \tilde{w}^* \tag{5.20}$$

This growth rate is constant as long a $\tilde{w}^*$ is constant. If this was not the case, the steady-state might not be stable.

Proposition 3. *The growth rate with complete specialization of the small country is higher than with incomplete specialization.*

Proof. I need to show that $(1-\alpha)\lambda \hat{n} \ln \gamma < \lambda L \ln \gamma - \alpha \tilde{w}^*$, where the left-hand-side is the growth rate with diversification, multiplied by $(1-\alpha)$ and the right hand side the growth rate with specialization. Rearranging the latter expression yields $(\hat{n} - L)\lambda \ln \gamma < \alpha(\lambda \hat{n} \ln \gamma - \tilde{w}^*)$. The left-hand-side of the inequality is negative as the research employment with diversification is below the one with specialization $\hat{n} < L$. The right-hand-side is positive by assumption which proves the proposition. □

[5] Nevertheless, the wage paid to the foreign workers grows.

The intuition behind this result is that if the wage gap increases, the small economy's income grows faster than the effective costs of the imported tasks. Accordingly, it realizes gains from increased use of the intermediate in production.

5.3.2 Gains from Trade

In this section, I compare the steady-states of the small economy with and without offshoring. The case of no offshoring is denoted by a. I focus on a constant wage gap. The results can be extended to an increasing wage gap by referring to corollary 6.

Proposition 4. *The small country gains from offshoring from a reallocation effect, which increases the growth rate and current consumption possibilities.*

A formal proof of the proposition is found in the Appendix. The reallocation effect increases the fraction of workers in research. Despite an increase in final demand, the labour demand in the production sector falls as a share of the tasks is offshored to the rest of the world. Accordingly, jobs get relatively scarce in the intermediate sector, which decreases the wage. A lower wage opens profitable opportunities in the research sector, which are exploited by workers switching to research. Therefore, growth increases as more workers are employed in the research sector.

Offshoring increases the output in the final good sector as well. Although this effect is static, it is relevant to the dynamic analysis because the economy improves its growth prospects without diminishing current consumption possibilities. The reason is as follows. An intermediate producer can reduce her costs of production by offshoring. This fall in marginal costs implies an increase in the output of the intermediate good, given the monopoly behaviour of the intermediate producer.[6] The larger output is largely manufactured by foreign workers as they replace domestic labour. Additionally, the intermediate producer's profits increase, which implies a higher incentive for investment in research. Therefore, firms can only

[6] Given the production structure of the final good, the output of the latter increases as well.

produce more and, at the same time, invest more if the effective domestic labour endowment has increased. Otherwise it is not possible to increase the employment in research and production. The intuition is similar to Grossman and Rossi-Hansberg (2008) who find a productivity effect and a labour-supply effect. The productivity effect decreases costs and thus makes firms more profitable. The labour-supply effect increases the effective labour endowment in an economy. The two effects together cause an increase in both, growth and current consumption.

5.4 A Receiving Economy

I now analyze a small economy whose wage is below the worldwide wage, $w < w^*$. Accordingly, the small economy exports the finished tasks to the rest of the world. I continue to assume that all tasks have a unit input requirement a_x. I do not make any assumptions on the technology of task production in the rest of the world, as the worldwide technology has no direct impact on the small country. This might change if offshoring includes technology transfers from the rest of the world to the small economy.

I build on the previous discussion of the model for the offshoring economy. The mechanics of the model are the same. I therefore introduce the changes and skip the detailed derivation of the model.

Proposition 5. *Let the small economy have a lower wage than in the rest of the world. If the wage gap is sufficiently large, the economy specializes in the production of tasks which it exports.*

If offshoring is possible, a producer of a task faces the decision either to export the finished task or sell it to a domestic intermediate producer. Research might eventually cease. The reason is as follows. The domestic wage is determined by the entry condition into research $w = \lambda V$. A producer of a task takes wages in the economy w as given. If a producer of a task is able to sell the task on a world market, the producer can pay a trade-cost adjusted wage of $w_s \equiv w^*/\tau(J)$ to a worker. By the law of one price, w_s will be the new wage rate in the economy if

$w_s \geq w$. What happens to research? If $w_s > w = \lambda V$ then the economy stops investing in research because the cost of research exceeds the expected benefits of research. Therefore, the economy completely specializes in the production of tasks.

The wage gap is sufficiently large if the export price of a task is higher than the price of the same task for domestic usage in the domestic economy. The wage in the domestic economy is determined by the no-arbitrage condition in equation (6.14). Research firms hire labour at the prevailing wage to do research. Labour in the economy can sell its services either to foreign firms to produce tasks or to the domestic sectors - either in research or intermediate production. If foreign firms are willing to offer a wage for the production of tasks that is higher than the wage in the domestic sectors, then all workers would be working in the production of tasks. The formal condition is $w_s > w = \lambda V$, where w_s is the wage offered for the production of tasks by foreign firms. Is this likely to happen? To answer this, I look at the condition for the marginal tasks $w^* \geq \tau(J)w_s$. Foreign firms are willing to pay a wage that is higher than the domestic one as long as they can still realize their cost savings. Therefore, if $w^*/\tau(J) \geq w_s > w$ the economy specializes in the production of tasks. This proves the proposition.

I now analyze how exporting tasks affects the economy with incomplete specialization. Additionally, I assume that the wage gap is constant. The main impact of offshoring in the recipient country is that domestic labour is diverted from the production process for domestic purposes to the export production of tasks. Therefore the labour market clearing is

$$L = L_x^* + L_x + n \tag{5.21}$$

where L_x^* denotes the labour used to perform tasks that are offshored. Using labour demands and rearranging the equation I obtain

$$x^* = \frac{L-n}{a_x} - x^* \int_0^J \tau(j)dj, \tag{5.22}$$

where the second term on the right hand side is the value of exported tasks. Substituting the latter equation into the no-arbitrage condition yields

$$\hat{n} = \frac{\psi L - r}{\lambda + \psi} - \frac{\psi a_x x^* \int_0^J \tau(j)dj}{\lambda^* + \psi} \tag{5.23}$$

where $\psi \equiv \lambda\gamma(1-\alpha)/\alpha$. The first term on the right hand side is the autarky employment in research. The second term indicates the labour that is diverted from research into the production of the tasks for the source country. Therefore, the employment in research falls if the economy exports tasks.

5.4.1 Growth in a Receiving Economy

In analyzing growth, I can distinguish between three scenarios. Firstly, if the small economy grows faster than the rest of the world, the catch-up process of the small economy is slowed by offshoring due to a lower employment in research. Secondly, the small economy's growth rate is, or falls below, the growth rate in the rest of the world. In that case, the small economy eventually specializes fully in offshoring. Thirdly, the growth rate in the small economy jumps in par with the worldwide growth rate which implies an interior solution with respect to offshoring.

Corollary 3. *If the small economy is completely specialized in the production of tasks, it grows at the same rate as the rest of the world. Growth in this instance is measured in income growth.*

The proof of the corollary follows from the wage setting under complete specialization. The wage in the rest of the world grows at a rate $\tilde{w}^*$. For simplicity, I assume that labour in the small economy has set a wage $w_s = w^*/\tau(J=1)$. Log linearizing the latter equation and differentiating it with respect to time yields

$$g = \tilde{w}_s = \tilde{w}^*. \tag{5.24}$$

The reason is that if the wage in the rest of the world increases, a task producer can sell the task at a higher price and, due to perfect competition, the price change results in a higher wage. Accordingly, consumption possibilities increase with the wage.

I now look at the growth rate of the small economy with incomplete specialization. The derivation of the growth rate of the small country that does export tasks is similar to the country that offshores: I have to measure the increase in output with every innovation and then multiply it by the average number of innovations occurring in one period of real time. As I did previously, I assume that the wages in the small economy and the rest of the world grow at the same rate. Together with a sufficiently small wage gap, this implies incomplete specialization. The growth rate is

$$g = \lambda \hat{n} \ln \gamma. \tag{5.25}$$

Given that equilibrium employment has declined compared to autarky, growth is harmed in the small economy. The reason is that offshoring reallocates labour from research towards the production of the tasks. Therefore, less discoveries are made in the research sector in one unit of real time.

In the case of convergence of wages the growth rate increases until wages, are equalized with the rest of the world. If the small economy is still growing at a faster rate, it starts to offshore to the rest of the world.

5.5 Discussion

In this paper, I have shown that a country that offshores gains in terms of a higher growth rate. The reason is that it can utilize labour in the rest of the world to perform some or all of the tasks needed to produce the final good. The small economy can therefore increase its specialization in research which boosts growth.

I have further shown that a small economy that receives the offshored tasks can gain from offshoring, but only if it completely specializes in the production of tasks.

Appendix

Proof of Proposition 3

To prove the proposition, I firstly show that $\hat{n}-\hat{n}_a > 0$, where a indicates autarky. Then I show that the output in the final good sector increases as well.

For an economy that offshores tasks, the growth rate is higher if it has a higher employment in research. Therefore,

$$\begin{aligned} \hat{n}-\hat{n}_a &> 0 \\ \tfrac{\chi\Lambda(J)L-r}{1+\chi\Lambda}-\tfrac{\chi L-r}{1+\chi} &> 0 \\ (\Lambda-1)(L+r) &> 0 \\ \tfrac{\int_0^J \tau(j)dj}{\tau(J)(1-J)}(L+r) &> 0 \end{aligned}$$

where $\chi \equiv \lambda\gamma 1-\alpha/\alpha$ and $\Lambda \equiv 1+\{\int_0^J \tau(j)dj/[1-J]\tau(J)\}$. The first expression on the right hand side is always positive for $J \in [0,1)$. In the case of $J=1$, all labour moves to the research sector. This shows that an economy that offshores has a higher growth rate.

I now show that the output of the final good increases in every period as well. The proof is developed by comparing the steady-state of the economy with and without offshoring. In order to prove that the output of the intermediate good increases, I look at the no-arbitrage condition and rewrite it as follows:

$$r+\lambda n = \frac{\lambda\gamma\tilde{\pi}(\omega)}{\omega}$$

I define the difference between a steady-state variable with offshoring and without offshoring as Δ. Using the expression for the profits and differencing the two steady-states yields

$$\Delta n = \gamma a_x \frac{1-\alpha}{\alpha}\left[\Omega(J)x - x^a\right] \tag{5.26}$$

I know from the first part of the proof that the left hand side is positive and hence the right hand side must be positive as well. To see that the right hand side is positive, the expression in brackets must be positive. Therefore, $\Omega(J)x > x^a$.

Rewriting the latter inequality, I obtain the following series of inequalities, where the first inequality sign is shown in the text, $1 > \Omega(J) > x^a/x$. Accordingly, the final result is that the output must increase with offshoring, $x > x^a$.

Chapter 6

Growth, Offshoring and Heterogeneous Factors

6.1 Introduction

Offshoring has received a lot of attention in recent years. In this paper I investigate the long-term implications of offshoring for a small open economy. I show that an increase in the extent of offshoring has an ambiguous effect. In particular I highlight the role played by factor markets, namely the markets for skilled and unskilled workers. There are two channels which play an important role. Firstly, skilled workers' wage is raised by offshoring and, because skilled labour is the sole input in research, the investment costs increase. The incentive to invest in innovation is provided by the profits obtained upon successful innovation. Secondly, as unskilled workers jobs are offshored, the effective supply of unskilled workers increases, which allows the economy to produce more. This in turn increases the incentives to invest by increasing profits. However, only if the labour-supply effect is sufficiently large, the incentive to invest is increase enough to compensate for the increase in investment costs.

Most of the theoretical works have studied the static effects of offshoring for the economy.[1] On the dynamic side, (Glass and Saggi 2001) develop a one-sector,

[1] Examples are (Baldwin and Robert-Nicoud 2007), (Grossman and Rossi-Hansberg 2008),

one-factor growth model of quality ladders. They show that an increase in the extent of offshoring increases the aggregate innovation of an economy. The channel they emphasize through which offshoring operates is cost savings. I extend their result by introducing offshoring in a model of endogenous growth a la (Grossman and Helpman 1991a) with two factor endowments. Furthermore, I show that the efficiency gains of offshoring do not necessarily translate into a higher growth rate in an economy. Although a cost-savings effect is present in the model, I emphasize labour market spillovers. Due to the cost-savings effect, the costs the unskilled tasks that are necessary to produce one unit of output fall. Owing to this effect, unskilled labour is substituted for skilled labour. Only if the production becomes sufficiently unskilled labour intensive and skilled labour is able to reallocate in research has offshoring a positive effect on growth. This corresponds to the condition presented in the paper that the labour-supply effect must dominate the cost-savings effect, for offshoring to have a positive effect on the growth rate. Only in this case is the economy able to increase the output sufficiently to compensate for the increase in research costs and reallocate skilled labour to research.

(Jones and Kierzkowski 1990) regard offshoring as the spatial fragmentation of the production process, which is organized in production blocks linked by services.[2] In (Jones and Kierzkowski 1998) they remark that the effect of offshoring for the economy is similar to technological progress. My formulation of offshoring uses the one developed in (Grossman and Rossi-Hansberg 2008). They formalize offshoring as trade in tasks and focus on the wage effects of offshoring. In their work the number of tasks is fixed and the role of task specific trade costs is emphasized. A task is subject not only to transportation costs, but there might also be some additional cost of performing it at a distance. The often cited example is the job of a janitor which is hard to perform at a distance, whereas basic stages of accounting might be easy to offshore, given modern communication technology.

(Kohler 2004) and (Markusen 2005).

[2] See (Francois 1990c) and (Francois 1990b) for a more formal theory of service links and fragmentation.

The authors show that in a small open economy with two factors of production there is a productivity effect and a labour-supply effect associated with offshoring. Firstly, offshoring is cost reducing which they compare to a Hicks-neutral technology shock. This effect boosts wages of skilled and unskilled labour. Secondly, offshoring increases the effective supply of labour. This effect puts downwards pressure on unskilled labour's wages.[3]

The paper is organized as follows. In section two I develop the basic framework and derive the equilibrium conditions and the growth rate. In section three I analyze the effect of an increase in the extent of offshoring on the growth rate. In the final section I conclude.

6.2 The Model

The structure of the economy in the paper is depicted in figure 6.1. There are two final good sectors X and Y. Both final sectors use an intermediate input and either skilled or unskilled labour. I assume that both sectors use the same intermediates in order to be able focus on the role of offshoring on growth. Both final goods are traded. The intermediate sector uses skilled and unskilled labour to produce the input. Offshoring takes place in the intermediate sector and only unskilled tasks are offshored. Skilled labour is the only input used in research, where it invents new varieties of the intermediate input. Growth is modelled as an increase in the number of intermediate varieties[4].

[3]In their paper, there is a third effect which is called the relative price effect. By definition, this effect only occurs in a large economy. Although this effect is of interest by itself, it is not important for this work.

[4]Grossman and Helpman (1991c) show that this mechanism is similar to one with quality ladders except for the welfare analysis. I do not analyze welfare in this work. Therefore, the results hold in a quality ladder model as well.

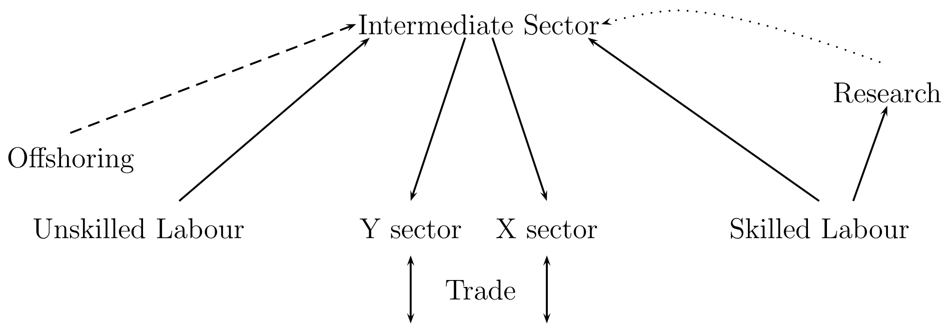

Figure 6.1: Overview of Economy

6.2.1 Households

I assume an infinitely lived representative household which consumes two final goods, X and Y, at each period t. The intertemporal utility function of the household is $U = \int_0^\infty e^{-\rho t} \ln u(c_{xt}, c_{yt})dt$, where the instantaneous utility function $u(c_{xt}, c_{yt})$ is non-decreasing, quasi-concave and homogeneous of degree one in consumption. The household faces both a static- and a dynamic-optimization problem. Firstly, the household maximizes instantaneous utility in each period by optimizing expenditures E_t on the two final goods. This yields the indirect per period utility $v_t = \ln \nu(p_x, p_y) + \ln E_t$, where p_i is the price of the final good $i = X, Y$. Secondly, a household optimizes its pattern of expenditures over time such that lifetime utility is maximized. Substituting the indirect per-period utility, the formal dynamics problem of the household is

$$\max V = \int_0^\infty e^{-\rho t}(\ln \nu(p_x, p_y) + \ln E_t)dt \tag{6.1}$$

subject to

$$\int_0^\infty e^{-R(t)} E_t dt \leqslant \int_0^\infty I_t dt + W_0$$

where I_t is the income of a household in period t and ρ is the subjective discount rate. $R(t) = \int_0^t r(s)ds$ is the cumulative discount rate depending on the interest rate r_t. Wealth in the initial period is denoted by W_0. From the maximization follows the optimal path of expenditures, which is

$$\frac{\dot{E}}{E} = r - \rho, \tag{6.2}$$

where the dot indicates a change over time.

6.2.2 Production

I assume that the economy is endowed with skilled workers H and unskilled workers L. The composition of skills in the economy does not change over time in the sense that technological progress increases the effective endowments of both skilled and unskilled labour, leaving the effective relative endowment unchanged. Due to homothetic preferences, I do not have to distinguish between the two types of workers but can consider a representative household. The endowed factors are perfectly mobile within the economy, but not internationally. Each of the final goods uses one of the factors and a continuum of intermediates in its production process. I assume that the X sector uses skilled workers and the Y sector uses unskilled workers. The intermediates are assumed to be capital inputs that are used in both sectors. Let Z_i denote the aggregate index of intermediates used in sector $i = X, Y$. I assume that both final goods are traded, whereas the capital goods are for domestic use only. The final goods are produced using the production functions

$$\begin{aligned} X &= BZ_X^{\beta} H_X^{1-\beta} \\ Y &= BZ_Y^{\beta} L_Y^{1-\beta}. \end{aligned} \tag{6.3}$$

where β is the input share of the intermediate input and B is a constant. Both sectors are perfectly competitive. From minimizing cost in each final good sector I obtain

$$\begin{aligned} p_X &= w_H^{1-\beta} P_Z^{\beta} \\ p_Y &= w_L^{1-\beta} P_Z^{\beta} \end{aligned} \tag{6.4}$$

where w_k is the wage of factor $k = H, L$ and P_Z is the aggregate price index of the intermediate sector. To simplify, I normalize $B \equiv 1/[(1-\beta)^{1-\beta}\beta^{\beta}]$. I assume that the economy is small compared to the rest of the world and thus takes prices of the traded goods as given. From (6.4) I can rewrite

$$\frac{p_x}{p_y} = \left(\frac{w_H}{w_L}\right)^{1-\beta}, \tag{6.5}$$

which implies that the relative factor price in the economy is fixed.

Each capital input, indexed by ω, is manufactured by a different producer. The aggregate output index takes the functional form $Z_t = \left(\int_{\omega\in\Omega} z_{\omega t}^{\sigma} d\omega\right)^{\frac{1}{\sigma}}$, where $z_{\omega t}$ is the output of each individual producer. The intermediate inputs are substitutes with $0 < \sigma < 1$ and an elasticity of substitution between any two varieties of $\varepsilon = 1/1-\sigma > 1$. The number of potential varieties is infinite. I assume, however, that varieties have to be invented before they can be used in the production of a final good. I denote the set of existing varieties by Ω_t. As I will show, Ω_t grows over time which implies productivity gains in the economy. For simplicity I skip the time subscript of the number of varieties. Let p_z be the price set by a particular intermediate producer. The implied aggregate price index of Z is

$$P_Z = \left(\int_{\omega\in\Omega} p_z^{1-\varepsilon} d\omega\right)^{\frac{1}{1-\varepsilon}}. \tag{6.6}$$

Each producer of a capital input maximizes profits, facing a downwards sloping demand curve,

$$z_\omega = Z\left(\frac{p_z}{P_Z}\right)^{-\varepsilon}. \tag{6.7}$$

The capital input is produced by using skilled and unskilled workers. I assume that unskilled workers have to perform a continuum of tasks in order to provide one unit of a labour input. To simplify the analysis I assume that a tasks needs one unit of labour input. The development of trade in tasks follows Grossman and Rossi-Hansberg (2006). I normalize the mass of tasks to be from zero to one. It is assumed that all tasks are offshorable. However, each task has a specific trade cost $\tau_j > 1$, where j indexes the task. I further assume that tasks are ordered such that trade costs are non-decreasing in j, which orders the task according to their offshorability. A firm offshores a task as long as it is cheaper to import the task than produce it at home, i.e. if

$$w_L \geq w_L^* \tau_j, \tag{6.8}$$

where the asterisk denotes the rest of the world. Each of the intermediate producers offshore up to the point where there are no more cost savings possible. Let J denote the marginal tasks for which a firm is indifferent between offshoring or domestic production and equation (6.8) hold with equality. The marginal task is a function of the wages of unskilled workers at home and in the rest of the world, $J \equiv J(w_L, w_L^*)$. For simplicity, however, I skip the arguments and denote the marginal task by J.

The wage of unskilled workers in the rest of the world is assumed to be lower than in the domestic economy, $w_L^* < w_L$ for a marginal task to exist. Further, I assume that the wage of unskilled workers in the rest of the world grows at the same rate as the domestic wage. I make these assumptions in order to ensure that the marginal task exists over time and no corner solution arises.

The production function of a capital input is assumed to be $z(\omega) = \Lambda \psi_\omega^\alpha H_\omega^{1-\alpha}$, where Λ is a parameter and ψ is the aggregate index of tasks performed. Note that due to the assumptions made on the tasks, I can think of them as a Leontief technology; each task has to be performed exactly once to produce one unit of the labour input. Cost minimization yields a unit cost function of $\tilde{c}(w_L, w_L^*) \equiv \Theta(J)^\alpha c(w_L)$, where $c(w_L) = w_L^\alpha w_H^{1-\alpha}$. The second expression in the unit costs is

$$\Theta(J) \equiv 1 - J + \frac{\int_0^J \tau(j) dj}{\tau(J)}. \tag{6.9}$$

The intuition for $\Theta(J)$ is that it is a cost savings parameter. If the economy is able to offshore a fraction of the tasks, domestic labour is replaced by lower cost labour from the rest of the world, which reduces the costs of production. This is similar to an increase in the productivity of domestic labour.

The behaviour of each intermediate producer is characterized by a mark-up over marginal costs. The pricing rule is

$$p(w_L, w_L^*) = \frac{\tilde{c}}{\sigma} \qquad \forall \omega \in \Omega_t, \tag{6.10}$$

where I have dropped the arguments on the right hand side. The mark-up is set over effective marginal costs. The price of a single variety falls in the effective marginal costs. The per-period profits of an intermediate producer is

$$\pi_\omega(w_L, w_L^*) = (1-\sigma)\, p_z z(\omega) \qquad \forall \omega \in \Omega_t. \tag{6.11}$$

Due to symmetrical producers, all capital input producers set a price equal to equation (6.10). Therefore, I can rewrite the aggregate price index in (6.6) as

$$P_Z = n^{\frac{1}{1-\varepsilon}} p_z, \tag{6.12}$$

where n denotes the number of intermediate producers in period t.[5]

6.2.3 Research

Before entering the production stage in the intermediate sector, a potential producer of a capital input must invest in research and development of a blueprint for a new capital input. With the invention of a blueprint, the innovator receives a patent. I assume that inventing around the patent is prohibitively costly and thus an incumbent intermediate producer faces no (direct) competition for her variety because the latter is protected by the patent. I assume that patents are non-contractible.[6] Therefore, an intermediate producer that invests in research and development also becomes the producer of the capital input. I assume that research uses human capital as its sole input.

A potential entrant makes an investment if the cost of the investment is not larger than the present discounted profits it earns from its investment. Let v be the present discounted value of an investment and aw_H/K the investment cost.

[5]It holds that $n_t = \Omega_t$ in each period. Otherwise some firms would invent blueprints which are not used.

[6]This assumption is made analogous to Grossman and Helpman (1989).

The investment cost is composed of the input requirements of human capital a, the wage the producer has to pay to employ one unit of human capital in research and the capital stock K. The capital stock K represents the existing experience in the economy in research. With each new variety the capital stock increases. Therefore, successful research has a positive externality on the investment costs. I make the assumption that the capital stock equals the number of already invented varieties, $K = n$.[7] Therefore, investment costs decline over time, which permits more entry into the intermediate market. I assume free entry into the intermediate market. Accordingly, all the blueprints are marketed. If that was not the case, some R&D investment would be wasted. The free entry condition is

$$\int_0^\infty e^{-R(t)}\pi(t)dt = \frac{aw_H}{n}. \tag{6.13}$$

The discounted profits of successful innovation must equal the costs of developing a variety. If the costs are lower than the intertemporal profits then profitable opportunities exist in innovation. Differentiating equation (6.13) with respect to the initial period yields

$$r = \frac{n\pi}{aw_H} + \frac{\dot{w}_H}{w_H} - \frac{\dot{n}}{n} \tag{6.14}$$

which is a no-arbitrage condition. The intuition is similar to the one of the free-entry condition. Potential investors are able to issue a bond on the financial market to finance research. The issuer of the bond has to pay interest r per period. The return from inventing a blueprint is the pure profits in the period of invention and the evolution of the future profits. An investor would issue a bond as long as rent payment of the bond is not more than the return of investment, with equality in equilibrium.

6.2.4 Equilibrium Conditions

An equilibrium in the economy is characterized by a steady state, where all variables grow at a constant rate. I define $g \equiv \dot{n}/n$ to be the growth rate of new

[7] See Grossman and Helpman (1991b) for further discussion.

varieties.[8] For the economy to be in equilibrium, the no-arbitrage condition in (6.14) must be satisfied and the factor markets have to clear. Each final good sector indirectly uses both factors. For example, the X sector uses skilled workers directly in its production and unskilled workers indirectly in the form of the capital input. Let a_{ki} denote the unit-input coefficients of input $k = H, L$ used in sector $i = X, Y, Z$. Further, let a_{ZX} and a_{ZY} be the unit input coefficients of the capital good in the respective final good sector. The input coefficients are derived from the unit-cost functions of the final good sectors in equation (6.4) and using Shepard's lemma. The detailed derivation of the unit input coefficients is found in the appendix. The demand for skilled workers from the research sector is its input requirements a/n multiplied by the number of new entrants $\dot{n}$. Therefore, I write the factor market clearing conditions as

$$\begin{aligned} H &= a_{Hz}(a_{ZX}X + a_{ZY}Y) + a_{HX}X + ag \\ L &= (1-J)a_{Lz}(a_{ZX}X + a_{ZY}Y) + a_{LY}Y. \end{aligned} \tag{6.15}$$

As has been assumed, offshoring affects the labour market clearing of unskilled labour only. An increase in marginal task J reduces the demand for unskilled labour from the intermediate sector. The input coefficients are affected by the introduction of new varieties. Rewriting the factor prices in their productivity-adjusted form enables me to solve for the equilibrium growth rate. Let the productivity adjusted wage be $\bar{w}_k \equiv w_k A^{\beta}$, where $A \equiv n^{\frac{1}{1-\varepsilon}}$. I therefore rewrite the pricing equations in (6.10) as

$$\begin{aligned} p_X &= c_X(\bar{w}_H, \bar{w}_L) \\ p_Y &= c_Y(\bar{w}_L, \bar{w}_H). \end{aligned} \tag{6.16}$$

I define the coefficients as $b_{HX} = a_{HX} + a_{Hz}a_{ZX}$, $b_{HY} = a_{Hz}a_{ZY}$, $b_{LX} = a_{Lz}a_{ZX}$ and $b_{LY} = a_{LY} + a_{Lz}a_{ZY}$. Given those definitions, I can rewrite the factor market clearing as

$$\begin{aligned} H &= b_{HX}\bar{X} + b_{HY}\bar{Y} + ag \\ L &= b_{LX}\bar{X} + b_{LY}\bar{Y} - Ja_{Lz}(a_{ZX}X + a_{ZY}Y) \end{aligned} \tag{6.17}$$

[8] Solving for the equilibrium follows Grossman and Helpman (1991a)

where $\bar{X} = XA^{\beta}$ and $\bar{Y} = YA^{\beta}$ are the productivity-adjusted final outputs. Multiplying both equations in (6.17) with the respective effective wage $\bar{w}_k$, adding them together and using the appropriate definitions of the unit input coefficients yields

$$\bar{w}_L L + \bar{w}_H H = \chi_1 (p_X \bar{X} + p_Y \bar{Y}) + \bar{w}_H a g, \tag{6.18}$$

where $\chi_1 = \{1 - \beta + \beta\sigma(1-\alpha) + \alpha\beta\sigma(1-J)/\Theta\}$.

I now turn to the evolution of the expenditures in the economy. Expenditures in this economy are not equal to output. Trade must be balanced and hence the import value of final good and tasks must equal export value. Therefore, the per period expenditures in the economy are the value of the production less the cost of the imported tasks, $E = p_X X + p_Y Y - \textit{import value of tasks}$. In the Appendix I show that this results in

$$E = \chi_2 (p_X X + p_Y Y), \tag{6.19}$$

where $\chi_2 = 1 - \alpha\beta[\int_0^J \tau(j)dj]/[\theta(J)\tau(J)]$, with $\chi_2 \in [0,1]$.[9] I will refer to χ_2 as the wedge between the value of the output in the economy and domestic expenditures. The growth rate of the expenditures is

$$\frac{\dot{E}}{E} = \beta \frac{1}{1-\varepsilon} g, \tag{6.20}$$

which is derived in the appendix in more detail. Equation (6.20) implies that the growth of expenditures is proportional to the growth of varieties. In deriving this result, the assumption that the wage in the rest of the world grows at the same rate is important. If the growth rate would be different, the growth path of the import costs might have a positive or negative impact on the growth path of the expenditures.

[9] It is straight forward to show the upper bound. For the lower bound, note that $1 - \alpha\beta[\int_0^J \tau(j)dj]/[\theta(J)\tau(J)] \geq 0$. I can rewrite the latter expression as $1 \geq \Theta(J) \geq \alpha\beta[\int_0^J \tau(j)dj]/\tau(J)$. The first inequality in the second expression is from the definition of $\Theta(J)$. This proofs the lower bound.

Finally, I rewrite the no-arbitrage condition in (6.14) using (6.20) and the expression for the profits in (6.11). Therefore,

$$\beta\frac{1-\sigma}{a\bar{w}_H}(p_x\bar{X}+p_y\bar{Y})=g+\rho. \tag{6.21}$$

The no-arbitrage condition links current output to the growth rate, showing the trade-off the economy faces. For example, if more resources are invested in research, current output reduces, but future consumption possibilities are enhanced.

6.2.5 Equilibrium

I am now able to discuss a steady-state growth rate in the economy. In an equilibrium, the economy must satisfy the resource constraints in (6.18) and the no-arbitrage condition in equation (6.21).[10]

I proceed with a graphical presentation of the equilibrium and the trade-off between current output and growth. The resource constraint and the no-arbitrage condition are drawn in figure 6.2 with the effective per period output Q on the vertical axis and the growth rate g on the horizontal axis. The RR line represents the resource constraint. The negative slope of the resource constraint reflects the trade off between growth and current output. For instance, if more skilled workers are employed in research, less skilled workers are available for production. The AA line represents the no-arbitrage condition. This line is upwards sloping because a higher current output implies higher profits and therefore a bigger incentive to invest in new blueprints, thereby increasing the growth rate. Both constraints are linear if the economy is diversified. In case of specialization, both constraints become none-linear. The equilibrium is found at the intersection of the resource constraint and the no-arbitrage condition and is denoted by G.

[10] I consider an economy that is diversified in the production of both final goods, which is the case if the economy grows at a moderate rate. However, if the growth rate is too high in the economy, all skilled labour is employed in research and the production of the capital input.

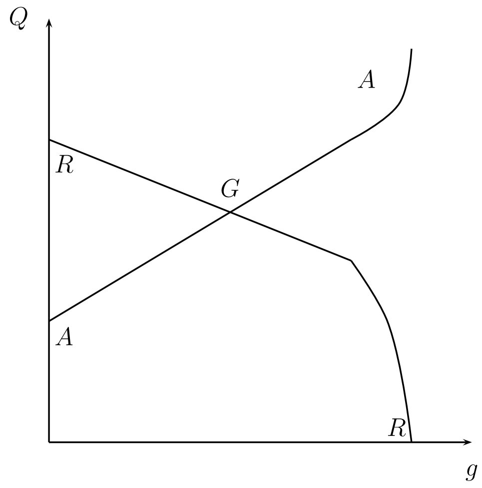

Figure 6.2: Equilibrium

For the analytical solution, substituting the resource constraint into the no-arbitrage condition (6.14) yields

$$g = \frac{\eta}{a(1+\eta)}\left(\frac{w_L}{w_H}L + H\right) - \frac{1}{1+\eta}\rho, \tag{6.22}$$

where $\eta \equiv \beta\frac{1-\sigma}{\chi_1}$. By assumption, the growth rate is positive. The basic structure of the growth rate is that growth is increased if either or both of the endowments increase. Growth decreases with an increase in the discount rate, as consumers become more impatient and invest less.

6.3 Offshoring and Growth

How is the growth rate affected by the extent of offshoring? If offshoring affects the allocation of factors of production, growth is affected as well. On the one hand, unskilled workers lose their jobs in the intermediate sector as offshoring enables intermediate producers to reduce their costs by moving tasks overseas. On the other hand, due to the reduced costs, the intermediate sector might expand its output, which might absorb the job losses and the two effects might cancel each other out. In this section, I show that an increase in the extent of offshoring has an ambiguous effect on growth. To this end I assume that the economy is initially in a steady state when it experiences the shock and I compare it to the economy after the adjustment process. However, before I investigate the link of offshoring and growth, I develop some results that are helpful to build an intuitive understanding for the underlying mechanisms.

Throughout this section I consider an increase in the extent of offshoring. The extent of offshoring is measured by the marginal task J. If J increases, a larger fraction of tasks is offshored. Two reasons for a shift in the marginal task exist. Firstly, the wage in the rest of the world falls. To fix ideas, by the condition for the marginal task in equation (6.8) I see that J has to increase if the domestic wage remains constant.[11] Secondly, the transportation costs of the task falls. For example, communication links to the rest of the world improve, which reduces the costs τ. If the transport cost for each individual task falls, then, by equation (6.8), J must increase. In terms of their effect on the marginal task, both reasons are equivalent. However, I will restrict the analysis in this section to a fall in trade costs in order to be able to track down the effect of the change of cost savings parameter $\Omega(J)$.[12] In my discussion, I follow Grossman and Rossi-Hansberg (2008) and assume a uniform fall in the trade costs of all tasks. Formally, I assume that the trade costs fall by $\nu < 1$, where $(1-\nu)\tau_j$ is the new level of trade costs of task j. Inspecting the definition of Θ in (6.9) reveals that it is only affected by a change in J and not affected by change in the trade costs itself.[13]

Proposition 6. *Let the extent of offshoring, J, in the economy increase. Then the productivity adjusted wage $\bar{w}_i$ of each factor $i = L, H$ increases.*

Proof. Totally differentiating the log of the pricing equation (6.27) in the Appendix for either final good sector, yields $\hat{p}_i = \alpha\hat{\Theta} + \alpha\beta\hat{\bar{w}}_k + (1+\beta-\alpha(1+\beta))\hat{\bar{w}}_{-k}$,

[11] Below I show that the domestic wage is not fixed, but J must change nevertheless.

[12] A fall in the trade costs is similar to a cost reduction in service links in (Jones and Kierzkowski 1990).

[13] For a discussion of a proportional fall in trade costs, see Grossman and Rossi-Hansberg (2008)

where the hat indicates a percentage change and $k \in H, L$. Note that the change in both wages must be equal, $\hat{\bar{w}}_H = \hat{\bar{w}}_L$, because the relative factor prices are determined by the relative final price which is unchanged. Taking this into account results in

$$\hat{\bar{w}}_k = -\alpha\beta\hat{\Theta} \quad k = H, L,$$

This establishes a positive correlation between wages and offshoring. $\square$

Domestic unskilled labour is mixed with cheaper foreign unskilled labour which raises the effective productivity of domestic labour. As with Hicks-neutral technological progress, the marginal product of labour increases and this increases the return for labour. This is the productivity effect in Grossman and Rossi-Hansberg (2008). Offshoring reduces the costs in the intermediate sector. These cost savings are passed on to the final good sectors which become relatively more intensive in their use of capital inputs.[14] The substitution effect raises the marginal product of the respective factor. In combination with constant final good prices the factor prices must increase.

Will all factors in this set-up support offshoring? In a standard HOS model, the Stolper-Samuelson theorem indicates that not all factors of production gain from liberalizing final goods trade. In this model, none of the factors has an incentive to oppose offshoring because they all gain from higher wages, as shown in proposition 6.

I now turn to the analysis of the growth rate in equation (6.22). The result I am interested in is a marginal change of the extent of offshoring on the rate of growth. This implies that I have to find the sign of

$$\frac{\partial g}{\partial J} = \frac{\partial g}{\partial \eta}\frac{\partial \eta}{\partial J}. \tag{6.23}$$

[14]The aggregate price index in the intermediate sector is $P_Z = \Theta^\alpha \bar{w}_L^\alpha \bar{w}_H^{1-\alpha}$. Rewriting the latter expression in percentage changes and using the extent of the wage changes given in the above proof yields $\hat{P}_Z = \alpha(1-\beta)\hat{\Theta}$, which is a smaller one but positive if J increases.

The first derivative, $\partial g/\partial\eta$, is always positive. Using the definition of η, its derivative is

$$\frac{\partial\eta}{\partial J} = -\beta\frac{1-\sigma}{\chi_1^2}\frac{\partial\chi_1}{\partial J}, \tag{6.24}$$

where a prim indicates the derivative with respect to J. The sign of the derivative depends on the sign of $\partial\chi_1/\partial J$, which is negative if $-\epsilon_\Theta < \frac{J}{1-J}$, where $\epsilon_\Theta < 0$ is the elasticity of cost-savings Θ with respect to the marginal tasks J. The latter condition states that the additional cost savings of offshoring around the marginal costs might not be too large for all $J \in [0,1]$. To summarize this paragraph:

Corollary 4. *Let the extent of offshoring increase. Then the growth rate increases if $-\epsilon_\Theta < \frac{J}{1-J}$ and decreases if $-\epsilon_\Theta > \frac{J}{1-J}$. In the case of $-\epsilon_\Theta = \frac{J}{1-J}$ offshoring has no effect on growth.*

How can I explain the intuition of the effect of offshoring on growth? In figure 6.3 I depict the resource constraint (RR) and the no-arbitrage condition (AA). I solely focus on the linear part of the two constraints. From proposition 1 follows that the return to both factors of production increases. Accordingly, research becomes more expensive, which discourages firms to invest, given the free entry condition in equation (6.13). Hence, the no-arbitrage condition tilts upwards as depicted in the figure. A tilt upwards implies that domestic output must increase to be able to achieve a given growth rate. The total output has a positive incentive to invest in research. An increase in total output implies an increase in profit opportunities for firms as the market increases. Thus, with an increase in the market, more firms enter the market. From figure 6.3 I can see that, if the resource constraint would not change, the growth rate would decrease and the expenditures would rise.

To analyze the shift of the resource constraint I start by considering a positive effect of offshoring on growth. It is easy to show that the resource constraint shifts out and has a steeper slope. The new resource constraint is depicted by $R'R'$. The shift is a result of the increase in the wages and the corresponding increase of the factor income. The change in the slope is a result of the increase in the relative costs of research; investing in research becomes more costly relative to consumption. Thus, for a given output, consumers prefer to invest less.[15] In order to achieve a higher growth rate, the shift in the resource constraint must be large enough for the equilibrium to be to the right of the dotted line, which represents that pre-change growth rate. Thus, with a sufficient shift of the resourced constraint, the increase in output is large enough to compensate for the increase in the costs of research.

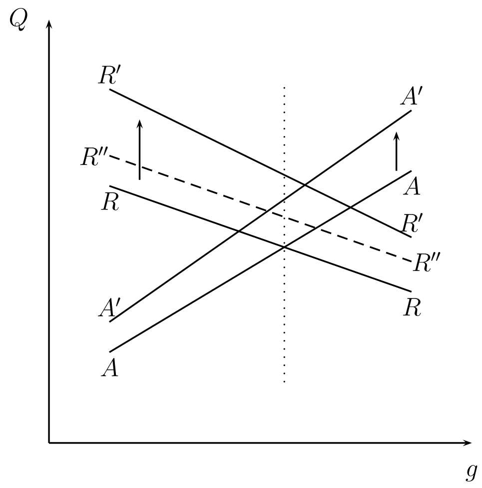

Figure 6.3: Equilibrium with an increase in J

In case of a slowdown in growth due an increase in the extent of offshoring, the resource constraint, which is labelled $R''R''$, shifts out as well. The new no-arbitrage condition is still given by the $A'A'$ line. In this case the new equilibrium growth rate must be to the left of the dotted line. Therefore, the shift in the resource constraint is not sufficiently large enough to compensate for the increase in the research costs and thus growth reduces.

[15]Strictly speaking there are no savings in the economy. However, savings are interpreted as investing resource in research and not consuming them.

So far I neglected the intuition of the shift size of the resource constraint. I can rewrite the condition $-\epsilon_\Theta < -\epsilon_{1-J}$, where $\epsilon_{1-J} \equiv -J/(1-J)$ is the elasticity of the labour-supply effect. Then the condition states that the size of the cost savings must be smaller than the size of the labour-supply effect. The intuition is that with an increase in the extent of offshoring, unskilled labour is freed on the one hand. On the other hand, the demand for unskilled labour increases. The reason for an increase in the demand for unskilled labour is that the price of one unit input of unskilled labour tasks falls due to the cost savings of offshoring. Therefore, the production of the intermediate inputs becomes relatively more unskilled labour task intensive. Additionally, the final good production becomes relatively intermediate intensive due to a fall in intermediate prices. Both changes in relative intensities increase the relative demand for unskilled tasks. Accordingly, only if the labour-supply effect dominates, sufficiently enough unskilled labour is able to substitute for skilled labour which can be reallocated to research to increase the growth rate.

6.4 Conclusion

In this paper, I showed that an increase in the extent of offshoring has an ambiguous effect on growth in an economy. The driving factors of this effect are labour market spillovers. If the economy is able to increase the effective unskilled labour supply sufficiently, skilled labour is substituted in the production and reallocated in research. Hence, the costs savings of offshoring are important to induce a substitution effect in production. This result holds although offshoring has no effect on the relative wage in the economy. The reason is that the relative input prices change due to offshoring are important, as an increase in the extent of offshoring raises the wage of skilled labour, which makes research more expensive. For offshoring to have a positive effect on growth, the output in the economy must increase to offset the reduced incentive to enter research by the increase of the research costs.

Appendix

Unit Input Coefficients

In this section, I derive the unit input coefficients. I start with the pricing equations

$$\begin{aligned} p_X &= A_Z^\beta p_Z^\beta w_H^{1-\beta} \\ p_Y &= A_Z^\beta p_Z^\beta w_L^{1-\beta}, \end{aligned} \tag{6.25}$$

where $A_Z \equiv n^{\frac{1}{1-\varepsilon}}$. The pricing rule for the intermediate input is

$$p_Z = \frac{\tilde{c}(w_L)}{\sigma}, \tag{6.26}$$

where $\tilde{c}(w_L) = \Theta(J)^\alpha c(w_L)$. Let the productivity adjusted factor prices be $\bar{w}_i \equiv w_i A_Z^\beta$ for $i = H, L$. I can therefore rewrite the pricing equations as

$$\begin{aligned} p_X &= \left(\frac{c_z(\bar{w}_L)}{\sigma}\right)^\beta \bar{w}_H^{1-\beta} \\ p_Y &= \left(\frac{c_z(\bar{w}_L)}{\sigma}\right)^\beta \bar{w}_L^{1-\beta} \\ P_Z &= \frac{\tilde{c}_z(\bar{w}_L)}{\sigma} A_Z^\beta. \end{aligned} \tag{6.27}$$

I define $p_X \equiv \bar{c}_X(\bar{w}_L)$ and $p_Y \equiv \bar{c}_Y(\bar{w}_L)$ to be the productivity adjusted cost functions of firms in the X and Y sector. The unit input coefficients are defined as the derivative of the cost function with respect to the input price. This results in

$$\begin{aligned} a_{HX} &= (1-\beta)\frac{p_X}{w_H} \\ a_{LY} &= (1-\beta)\frac{p_Y}{w_L} \\ a_{ZX} &= \beta\frac{p_X}{p_Z} \\ a_{ZY} &= \beta\frac{p_Y}{p_Z} \end{aligned} \tag{6.28}$$

I can now write the a's. $b_{HX} = a_{HX} + a_{Hz}a_{ZX}$

$$\begin{aligned} b_{HX} &= p_X\left(\frac{(1-\beta)}{w_H} + \frac{\beta\sigma a_{Hz}}{\tilde{c}}\right) \\ b_{LY} &= p_Y\left(\frac{(1-\beta)}{w_L} + \frac{\beta\sigma a_{Lz}}{\tilde{c}}\right) \\ b_{LX} &= p_X\frac{\beta\sigma a_{Lx}}{\tilde{c}} \\ b_{HY} &= p_Y\frac{\beta\sigma a_{Hx}}{\tilde{c}} \end{aligned} \tag{6.29}$$

Derivation of Expenditures

In the main text I state that $E = p_X X + p_Y Y -$ import value tasks. The import value of tasks is simply the aggregate demand for the tasks, which is $\int_0^J w_L^* a_{Lz}(a_{ZX}X + a_{ZY}Y)\tau(j)dj$. Using the definition of the $a's$ and the marginal tasks I am able to derive $E = \{1 - \alpha\beta[\int_0^J \tau(j)dj]/[\theta(J)\tau(J)]\}(p_X\bar{X} + p_Y\bar{Y})$, where I define the first term in brackets to be χ_2.

I can now determine the growth rate of the expenditures $\dot{E}/E$ by taking logs of the above expression and differentiating with respect to time. Prices and productivity adjusted outputs are constant and so is χ_2 if the marginal tasks is constant in a steady state. Expenditures grow at the same rate as wages $\dot{E}/E = \beta g/\varepsilon - 1$.

Derivation of Equation (6.21)

In this appendix, I derive the no-arbitrage condition in equation (6.21) in more detail. I start by considering the basic no-arbitrage condition in equation (6.14). If this condition holds, the investment sector is in equilibrium as no firms have an incentive to enter or exit research. Consumer optimization yields the condition (6.20), which I substitute in the no-arbitrage condition. The evolution of expenditures is determined by the prevailing interest rate r_t and the discount factor ρ. The correlation between change in income and the interest rate is positive. For instance, if the interest rate is high, consumers are willing to save more. Because savings must equal investments, income grows faster. I substitute the definition of the growth rate $g \equiv \dot{n}/n$, and the growth of the high skilled wage $\dot{w}_H/w_H = g\beta/\varepsilon - 1$. The growth of the skilled wage is derived from the definition of the effective wage, $\bar{w}_H = A^\beta w_h$, which is constant. As I argue in the text the growth rate of the expenditures is $\dot{E}/E = g\beta 1/(\varepsilon - 1)$. These substitutions yield the modified no-arbitrage condition

$$\frac{\beta}{\varepsilon - 1}g + \rho = \frac{n\pi}{aw_H} + \frac{\beta}{\varepsilon - 1}g - g. \tag{6.30}$$

The profits of an intermediate producer is given in equation (6.11). I rewrite the profit function by using $nz = nz_X + nz_Y$ which are the demands for the capital input from each of the final input sectors. The demands are $a_{ZX}\bar{X}$ and $a_{ZY}\bar{Y}$. Multiplying both demands with p_z yields $\beta(p_X\bar{X} + p_Y\bar{Y})$. Substituting this and making the appropriate cancellations yields the no-arbitrage condition in equation (6.21)

Chapter 7

Conclusion

In part I of this thesis, I argued that firms have an incentive to differentiate their products. If firms operate in an international market, governments have an incentive to support their domestic firm by announcing a policy schedule. The optimal policy can either be a tax or a subsidy. Due to the strategic nature of the investments in product differentiation, the optimal policy is a tax if the investments are strategic complements and a subsidy if the investments are strategic substitutes. A vast literature concerns itself with possible rules for strategic trade policy. The implication of this work for policy makers is that the policy depends on the strategic nature of the investments in product differentiation. In particular, the policy depends on the relative strength of the market-expansion effect to the free-riding effect. If the market-expansion effect is stronger than the free-riding effect, a tax is optimal.

In part II of this thesis, I considered the effect of offshoring on growth. I showed that offshoring has a positive impact on growth for a country that moves the production stages abroad. For a country that receives the offshored production stages, the impact on growth is ambiguous and depends on the degree of specialization. If the receiving economy is fully specialized in the production of offshored stages, growth increases despite no research taking place in the country. If the country is partly specialized, growth is slowed as less workers are employed in research. Further, I presented conditions under which offshoring increases growth in a two factor model where only one factor can be offshored. The increase in growth occurs despite the fact that the offshorable factor is not employed in research. For future research, it might be of interest to consider explicitly a policy in the frameworks developed in the thesis. It might well be of interest to consider two open economies in order to be able to study the effect of offshoring on the worldwide growth rate and on the convergence of the two economies in terms of growth and size.

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