The Price is Right?

Producer, Retailer and Consumer Decision Making within the U.K. Soft Drinks Market

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Declaration

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Abstract

The main thread that runs through this thesis is one of 'price'. The study is based on a combination of academic research and the experience gained through a thirty-year career working as a practitioner in the soft drinks industry. The thesis is supported throughout by access to high quality electronic point of sale (EPOS) data and rigorous econometric analysis.

The thesis contributes to existing research in two specific ways. The first relates to consumer decision making at point of purchase and the influence of the behavioural concept of left digit bias, with the associated practice of 'pricing in the 9's'. This is examined in chapter 1, which reviews the basis for the concept and the near century long history of existing literature on this behavioural heuristic. The chapter shows that the largest UK grocery retailers' pricing strategies are inconsistent with this substantive body of academic research, which proposes that profit optimisation is best delivered through the use of psychological 9 ending price points. Indeed, the study shows that across the top 100 grocery brands the three largest UK retailers, accounting for over 50% of the market, *actively avoid* the use of 9 ending price points.

The chapter further highlights a unique market where the actual brand owners themselves rather than retailers set the individual product price points. This occurs through the extensive use by retailers of price marked packs (PMP's) within the 34,000 UK Symbol and Independent (S&I) grocery stores in the UK. This study shows that brand owners, who choose and then print the prices on these packs, are some 18x more likely to use 9 endings than their three largest retail customers.

Finally, within these S&I stores the study takes advantage of a natural experiment where the iconic and popular UK soft drinks brand IRN-BRU increased its PMP level by 1p from 99p to a £1 ahead of any pricing moves from close competitor PMP's. Using two different, difference-in-differences (DiD) methodologies the analysis shows that the 1p increase and move away from a 9 ending to a round pound had no impact on unit sales.

The second area of research, which is the substantive part of the thesis and covered in both chapters 2 and 3 is a comprehensive review of the impact of the introduction of the UK Soft Drinks Industry Levy (SDIL) more commonly referred to as the sugar tax. The SDIL was both a surprising and significant exogenous shock to the industry when it was announced in March 2016 with a deferred implementation date of April 2018. The structure of this 'tiered tax on the use of sugar as a raw ingredient' was unusual in that some soft drink brands and categories

were already exempt, whilst for the remaining brands it could be partially or even fully avoided if substantial reformulation was undertaken.

Chapter 2 provides both an overview of the structure of the UK SDIL and existing literature on sugar taxes before focusing on the supply side response to this potential significant increase in the cost price of such a key ingredient. The analysis combines the EPOS data with longitudinal nutritional information and a variety of event-study specifications to show that all but a few global soft drinks brands reduced their sugar content and hence avoided the SDIL. Furthermore, the study shows that this reformulation accounted for the substantive part of the circa 6,600 calories per capita reduction delivered through the policy with more than 80% of the reduction occurring due to the decisions and actions taken by brand owners and producers in the two-year period *between* announcement and implementation date.

Chapter 3 considers the more traditional demand side impact of a sugar tax by analysing the way the SDIL was passed through to shoppers on the brands who choose not to reformulate. It shows that the tax was at least fully passed through with both some actual over-shifting and some significant mix effects creating an illusion of over-shifting. The analysis shows that consumers responded by reducing their consumption of levied drinks by around 18%, indicative of an inelastic response, especially in the drink-now and energy segments of the market. The analysis also reviews changes in the pricing of brands who were either exempt, or had reformulated to avoid the levy, and the substitution from regular into diet drinks in response to the SDIL. Finally, following the first inflationary plus increase in SDIL rates in April 2025, a practice that will now take place on an annual basis, the chapter examines the hypothesis that the retail price impact of these annual increases will be very different to the initial SDIL implementation, with significant over-shifting and some potential unintended consequences.

At the end of the 3 chapters there is a final section to the thesis which looks forward to consider future developments in both UK grocery market pricing and the UK SDIL. It considers the link between the SDIL and UK health outcomes, before discussing how the success of the SDIL could inform policy in other countries and other categories which contain products considered to be high in fat, sugar and salt (HFSS). With the Oct 2024 announcement that a consultation is to take place on the future development of the UK SDIL, the thesis concludes by considering what these policy developments might be, and what impact they may have on the market.

Motivation and Acknowledgments for the Thesis

Motivation for the Thesis

In early spring 1992 I was a 2nd year Economics undergraduate at the University of Liverpool. Whilst walking past the careers service office I saw a poster pinned to the noticeboard:

"Would you like to earn £3,000 and drive a company car this summer? – if so apply now for a Procter & Gamble (P&G) internship"

I vaguely recalled one of my Microeconomics lectures, where the name P&G had been used in conjunction with Unilever as an example of a classic duopoly. However, like many students I didn't spend much time either purchasing or using household cleaning products and hence didn't quite realise I would be applying to join a global blue-chip business famous for 'building brands' in the highly competitive world of fast-moving consumer goods (FMCG). Following a series of interviews, I was fortunate to be offered a place on the summer programme working across customers (sales development), consumers (brand development) and commercial (profit development).

I quickly discovered that P&G had two main brand building levers. The first lever was investing in their consumers through marketing to generate awareness, trial and loyalty to their brands. In the 1930's it was P&G who pioneered the eponymous 'soap opera' as a vehicle to deliver brand building advertising and by 1992 they were one of the leading advertisers on UK television. The second P&G lever was investing in their customers (mainly the large grocery retailers) to 'win at the first moment of truth', when the shopper stands in front of the shelf and makes their purchase choice. Specifically, this was agreed investment with the retailer to i) increase instore visibility and presence, and more substantively ii) to deliver to the shopper agreed price points and price promotions to influence consumer purchase behaviour.

What surprised me was the significant scale of the customer investment relative to the more visible and transparent investment in advertising. Each year multi-million £ investment levels were being agreed between P&G and the UK's leading retailers in joint promotional plans. I was also surprised by how little was understood about the impact these price promotions had on actual shopper behaviour. There was a sense of 'look, we did this price promotion last year and it is now in the base, so we should just do it again this year' rather than any deep understanding of the impact on shopper behaviour and hence the return on investment.

There was also a concerning trend across most of the categories in which P&G's brands competed of promotional escalation, with the standard '10% off' starting to increase to higher discount levels (20% - 30%) and the first multibuys or link-saves appearing on display ends[1]. The investment levels, as a % of total sales were increasing year on year, yet very little was being done to evaluate the effectiveness of this increasing investment. The fact that as an intern with just a two-week induction, I was given a project to review promotional effectiveness probably speaks volumes!

I was though, very keen to make a good impression and could see that whilst the customer management teams were price insight poor, they were sales data rich. Hence, I started using the available data and applied some basic time series regression from my studies to create some simple demand models to forecast the impact of different promotional price points and display levels.

At the end of the summer I knew I had only scratched the surface of what was possible through the use of applied economics in this data rich FMCG environment. I therefore created a proposal to continue working on the promotional studies throughout the final year of my degree. This meant lining up the University (submitting the work as a relevant dissertation), P&G (can I keep a computer[2] and have access to data such as advertising dates and media spends) and the Co-op (can I have access to store level EPOS data detailing unit sales and sales price per week). Fortunately, they all agreed and a week later a Co-op delivery lorry turned up outside my student digs to drop off a pallet stacked with boxes all filled with *printed sheets* of EPOS data detailing for each individual store, sales volumes and values for all the products sold in the laundry category. The subsequent research generated new shopper insight for both P&G and the Co-op and both influenced and help optimise the laundry category promotional strategy going forward.

In September 1993 I joined P&G full time and commenced my career in a variety of sales, marketing and commercial roles. After 10 years (in 2003) I left P&G and joined the board of AG Barr plc (AGB) as Commercial Director. My role was to lead the Commercial function and its resources (500 people and circa £50m of Commercial Investment) to grow the brands and hence grow the business.

[1] Ultimately this escalation would lead to "buy one get one free" promotions better known as BOGOF's becoming ubiquitous in UK grocery retailers by the end of the 1990's. In 2008 Morrisons ran a "buy one get **two** free" promotion on Pepsi Max 2L in the run in to Christmas.

[2] On the basis if you don't ask you don't get I asked to keep the company car as well – sadly I didn't get….

The job went well for the first 10 years, as sales ultimately doubled and profit trebled, and whilst the work was challenging there was plenty of low hanging fruit to be picked. However, after this first decade the opportunities were becoming harder to reach, the external environment was tougher and on reflection I realised I was starting to make more and more decisions based on a combination of experience and heuristics. In short, I realised a reset was needed.

My thoughts went back to my undergraduate research and this prompted a number of questions. Could there be the opportunity to take this type of analysis to the next level? Over the past 20+ years what developments had there been in economics and consumer decision making theory? How had econometrics developed to improve applied analysis? Would further study provide the necessary reset and improve the quality and robustness of my decision making on a day to day basis?

I approached the University of Strathclyde 'as a place of useful learning' and was incredibly fortunate to be assigned initially Alex and then also Markus as my supervisors. The first book Alex recommended that I should read was "Thinking, Fast and Slow" Kahneman (2011), which quickly provided the necessary evidence that I had made the right decision.

Acknowledgments

I'm very conscious that I haven't been a role model or 'normal' PHD student – even allowing for the part-time basis of the study. From the outset I knew that balancing the study whilst leading the AG Barr business was going to be challenging, what I hadn't quite factored in was some of the unexpected and unwelcome business impacts (such as the SDIL itself, Covid19, Brexit etc..) and personal challenges (family illness) that would accompany this journey. Without the continued and whole-hearted support of both Alex and Markus I would have fallen in a heap by the wayside a long time ago. I have nothing but the greatest respect for them both and I will always be thankful for their support, supervision and counsel. I would also like to thank the broader department at Strathclyde for all their help and encouragement along the way.

The wider board at AG Barr have also supported this study – both in terms of the permission to access the high-quality data held by the business and their continued personal encouragement. I strongly believe the real value of this study is reflected in the quality of the

business decision making and leadership that I have been able to show, specifically in relation to the SDIL and the recovery of the business post Covid19. The learning has undoubtedly been more than just ‘useful’ and both the time and financial investment has delivered a healthy ROI.

Finally, I want to thank my wife and best friend Melanie, for all her support and being beside me every step of the way on this journey.

It is a journey that has taken longer than expected, but one that has presented new opportunities (such as creating and teaching a Marketing course to final year Strathclyde students) and which has firmly taken me out of my comfort zone (presenting at international conferences).

It is also a journey which I hope doesn’t come to an end, and that I can use the knowledge and experiences gained as part of this study to continue to develop and foster closer collaboration between business and academia, to make a positive difference to the sustainability of the UK drinks industry and to inspire a new generation of future business leaders.

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Introduction

At the heart of this thesis is something very ordinary, something which most people will do on a daily basis, namely the simple act of standing in front of a supermarket shelf and making a purchase decision. Economic science has often been presented as a 'study of choice' (Robbins, 1932) *and the consistent theme that runs through this thesis is the impact that price can have on this purchase choice.*

The initial intention was to base the whole thesis on Behavioural Economics and to explore how the introduction of 'psychological plausible foundations' to neoclassical economic theory could help broaden the understanding of the way shoppers made actual instore purchase decisions (Angner, 2012) . With the UK Food Standards Agency (2023) recording the average purchase decision time of a UK grocery shopper at just 12 seconds, busy supermarket aisles seemed ripe for the study of what Kahneman (2011) would term type 1 'heuristic' vs type 2 'considered' decision making.

In the gap between my undergraduate study and the commencement of this further study it is behavioural economics that has arguably most firmly established itself as its own subdiscipline within economic science. The building of human behavioural concepts into traditional economic theories and models has broadened the impact and relevance of economic theory within academia, but also externally, impacting business, public policy and people on a day to day basis (Dickson & Fongoni, 2015). In short, could an understanding of this 'new branch' of economics help me become a better decision maker in my day job, and could my industry experience help further the existing knowledge of how these concepts could be successfully applied with shoppers and consumers?

On the 16th March 2016 the thesis plan took an unexpected development when the then Chancellor, George Osbourne made the surprise budget announcement that a Soft Drinks Industry Levy (SDIL), which quickly became more commonly known as the 'sugar tax' was to be introduced in April 2018. For some time, the soft drink industry as consumer centric brand owners[3], had been aware of changing attitudes towards sugar from both consumers and policy makers. However, it was believed that the strong track record of sugar reduction, coupled with long term voluntary pledges to continue this reduction trend had removed the likelihood of any regulatory policy intervention. Hence the SDIL announcement was an unwelcome surprise to the wider soft drinks industry and felt like an existential threat to the

[3] Some 17 out of the Top 100 Grocery brands are from the Soft Drinks Industry (The Grocer, 2025)

business I was responsible for. With brands such as IRN-BRU, Rubicon, Rockstar and KA the AG Barr business had a significant over-trade in full-sugar[4] drinks. A projected levy cost of circa £75m *at a time when the business made annual profits of some £40m, was deeply concerning.*

Hence there were elements of both necessity and opportunity in the decision to make the substantive part of this thesis the study of the impact of the UK SDIL. With access to much higher quality EPOS data than is normally available for academic study, there was an immediate awareness that the SDIL created a natural experiment well suited for an econometric evaluation. This development of the thesis also felt consistent with the original behavioural ambition, as it allowed the study to be widened to also consider the supply side effects of an unexpected exogenous pricing shock in the form of a very significant, but avoidable tax on the sugar used in soft drinks. At the time of the announcement a typical 2L bottle of full-sugar carbonated soft drink (CSD) in the UK would have had a sugar ingredient cost of circa 10p. The do-nothing scenario would effectively see this raw material price increase nearly six-fold to 58p (10p sugar and 48p SDIL) in April 2018. Furthermore, returning to the more traditional demand side and shopper behaviour, the median purchase price of the said 2L bottle in 2015 would have been at a £1 price point. With VAT automatically added to the SDIL the straight pass-through effect would see the retail price of this 2L bottle increase by some 58% to £1.58 (48p SDIL and 9.6p VAT). To my knowledge, in the UK's relatively stable inflationary environment, soft drink shoppers had never been presented with retail price increases of such a magnitude. Hence this thesis moves from retail price points, to cost of goods, to the impact of the soft drink sugar tax on the retail price paid by consumers; three chapters that are linked by a consistent thread of price.

At the end of this introduction is an overview of both the UK soft drinks market[5] and the data sources used in the analysis. As mentioned in the Abstract, this thesis benefits from long-term access to EPOS data covering the total soft drinks market in UK grocery retail. EPOS data is simply the digital recording of all the individual 'beeps' when the unique barcode on a purchase item is scanned through an EPOS till or checkout. Access to the data comes through a combination of my executive role at AG Barr plc, who purchase this data for commercial

[4] Full sugar – used within the industry to refer to drinks with added sugar – typically above 8 grams per 100ml of liquid.
[5] For a reader new to FMCG and the soft drinks category this section provides a helpful background foundation for the rest of the thesis.

reasons and the support of Circana (previously IRI) and RDP data who, subject to certain conditions, have kindly given their permission for the use of the data in this thesis.

The substantive part of the initial chapter focuses on a very specific behavioural concept – that of left digit bias and the practice of 'pricing in the nines' also referred to in the literature as 'psychological', 'odd' or sometimes 'charm' pricing. This is arguably one of the most relevant and impactful behavioural concepts for retailers and brand owners and their shoppers and consumers.

Retail price setting is one of the key decisions taken by a retailer and they have the sole responsibility to decide the shelf edge label price for each and every item they sell. These prices, and there will be over 20,000 of them in a large supermarket, will then be under constant review balancing the two key influences of profit margin return and market competitiveness.

The first of these influences flows from the retailer negotiating the cost price they pay for any given item from a supplier. There might be a minimum margin % they target or a category average margin that they buyer is striving to deliver across the brands they sell.

The second influence is the pricing decisions of the retailer's closest competitors. Each retailer must continually decide how they respond to competitors selling the same grocery item at a lower, higher or even the same price. This is particularly the case for known value items (KVI's) where higher levels of shopping basket penetration coupled with a higher frequency of purchase creates strong reference point expectations for shoppers. The price of a pint of milk or a loaf of bread are often cited as the best examples of dynamically priced KVI's.

The retailer also needs to decide a price point ending strategy. Do they run a 'cost plus model' that lets the price endings fall naturally based on cost inputs (in which case you would expect about 10% of prices to end in the digit 9) or do they actively choose to favour specific price points such as 9 and embrace the concept of left digit bias to deliver enhanced levels of perceived value? An aggregated analysis of 8 different price ending studies from 1964 through to 2023 would suggest 'just below' is a popular pricing strategy with an average usage of 9 endings in some 56% of observed price points.

So why does it matter if price points disproportionately end in the digit 9? In the year to w/e 22nd Feb 2025 UK Grocery market EPOS data for all categories sold in the store recorded some *59,813,523,870* 'beeps' when an individual items barcode was scanned through a till

(Circana 2025). If retailers can round up and charge 1p more on each of these beeps and see no impact on demand, it equates to some *£600,000,000* of additional pre-VAT profit.

This research highlights two recent studies, the first based on access to EPOS data (Strulov-Shlain, 2023) and the second based on disruptive digital technology (List, et al., 2023) which provide compelling evidence of the presence of left digit bias. Both studies also advocate harnessing the power of this behavioural effect to maximise the profit delivery by the firm. Yet as this study will show, the largest UK grocery retailers employ pricing strategies that are inconsistent with the substantive body of left digit bias literature and arguably look to *actively avoid rather than embrace the practice.* Across the 3 largest UK retailers we record *a 1.8% usage of 9 ending price points.*

The study further highlights one unique market where the retail price point and hence ending is set by the brand owner rather than the retailer. This occurs in the 'Symbol and Independent' channel (circa 34,000 UK convenience stores sometimes referred to as S&I stores, corner shops or 'mama and papa' stores) where in the soft drinks category the majority of retailers choose to sell Price Marked Packs (PMP's) produced by the brand owner. A PMP has a clear recommended retail price physically printed onto the label of the packaging.

The study uses this unique PMP market to consider whether, in contrast to their largest customers, the brand owners themselves embrace the extensive use of 9 ending price points. The answer to this question is undoubtedly yes – with some 18 times as many price points set by brand owners ending in the digit 9 compared to their three largest customers.

Finally, the substantive part of the study uses unique access to EPOS data for the S&I channel to generate new knowledge and insight by considering the specific question:

"Would a retailer or a brand owner maximise profit by selling a given product at 99p, or should they add 1p more and move to the 0 ending £1 price point?"

The research exploits a combination of access to high quality EPOS data at both an aggregated channel and store specific level, coupled with a natural experiment that was created when the popular UK soft drink brand IRN-BRU moved their PMP level from 99p to a £1 ahead of the equivalent competitors' PMP's. The study employs two different, difference-in-differences (DiD) methodologies and finds no evidence of any negative impact on demand through the implementation of the 1p increase.

The chapter ends by considering whether the findings of the analysis - that profit maximisation lies in a 'penny more', would be consistent across all price points or just applies to the magic of the move from 99p to a 'round pound'. The discussion also considers the possible reasons why the UK's largest retailers, who are clearly in the business of maximising profits, actively reject pricing in the 9's in favour of pricing based on quartile endings (round pounds, 25p, 50p and 75p ending price points).

Having considered the key aspect of behavioural pricing from a consumer, retailer and brand owner perspective, chapters 2 and 3 develop the study further through the introduction of a very significant, surprising and unprecedented exogenous pricing shock that impacted the UK soft drink industry from March 2016. The shock in question was the UK Soft Drinks Industry Levy (SDIL, or often referred to as the 'UK sugar tax') which was announced in the UK Budget in March 2016 with a deferred implementation date of April 2018. The structure of the SDIL placed responsibility for the levy payment on the manufacturers / importers of soft drinks sold within the UK. The SDIL had a unique tiering which provided the opportunity for all brand owners to fully or partially avoid the levy. If the sugar content of the drink exceeded a threshold of 5 grams per 100ml then a levy payment of 18 pence per litre (ppl) was required, this increased to 24 ppl above 8 grams per 100ml – but could be avoided completely should the liquid contain *or be reformulated to contain* below the 5 grams per 100ml. Some categories were exempt (fruit juice and milk-based drinks) on the basis of broader nutritional benefit from consumption.

The main contribution of these chapters and the balance of the thesis is to provide a detailed account of the UK SDIL, setting out the policy background and structure, industry response and perhaps most importantly disaggregating the supply and demand side effects to provide unique insight into how the SDIL delivered so successfully against its core policy objective of calorie reduction.

For perspective, this study estimates the annual per capita reduction in calories consumed from UK soft drinks post the levy introduction was just short of 6,600 per capita, relative to a counterfactual in which the SDIL was never introduced. This is of course an average, and for heavy consumers of soft drinks and specifically CSD's the reduction was significantly greater. For example, a person who drank a 500ml bottle of a regular 'Sugar Sweetened Beverage' (SSB) such as IRN-BRU with their lunch every day, and continued to do so post January 2018,

would have seen an annual calorie reduction of some 40,000+ calories[6] post the reformulation of the product to a level just below the lower threshold of the SDIL (5 grams per 100ml). Most likely this reduction took place without the drinker even realising anything had changed in their consumption behaviour and diet.

It is arguably the combination of academic rigour and methods, access to high quality data and the market experienced gained through leading a Soft Drinks business for over 20 years that creates the unique and impactful contribution of the study. It is a contribution that furthers knowledge within academia, public policy and government, but also within the global Soft Drink industry. The main insights from this research were shared at various conferences, and I was fortunate to be able to personally present and discuss them at the Royal Scottish Economic Society and the American Society of Health Economists annual conferences in April and June 2022 respectively.

A paper based on these studies was accepted for publication on a co-authored basis by *The Review of Economics and Statistics* in late 2023. All of the co-authors made a substantial contribution, engaged in drafting/revision, gave final approval of the article, and are equally accountable for its contents. In particular, I made a substantial contribution to the preparation of the data, the design of the research methodology, the implementation of this methodology, the interpretation of the results, and the writing up of these results. In 2024 / 2025 all of the co-authors were asked by a combination of His Majesty's Treasury and His Majesty's Revenue and Customs (HMT and HMRC) to share their perspectives on the future development of the SDIL and some specific areas of policy development.

Chapter 2 initially provides the background to the use of sugar in soft drinks and sets-out the taxonomy that supports the subsequent analysis where brands are split into 4 groups; 'non-reformulators', 'reformulators', 'diet drinks' (already below the threshold) and 'drinks in exempt categories'. The study provides a detailed overview of the both the structure of the UK SDIL and existing literature on sugar taxes before focusing on the *supply side* response to the announcement and the 'potential' significant increase in the cost price of sugar as a raw key ingredient. The study sets out the stark choice faced by most brand owners and through the access to EPOS data combined with longitudinal nutritional information and a variety of event-study specifications, shows that all but a few global soft drinks brands reduced their sugar

[6] An often-used heuristic in calorie counting is that a deficit of some 3,500 calories is required to lose a pound of weight – on this simplistic basis 40,000 calories equates to some 11 - 12 lbs of weight reduction.

content and hence avoided the SDIL completely. The study shows that this reformulation accounted for the substantive part (80%+) of the overall calorie reduction with the majority of the reduction occurring due to the decisions and actions taken by brand owners and producers in the two-year period *between* announcement and the April 2018 implementation date.

Chapter 3 considers the impact of the SDIL on retail pricing and the more traditional *demand side* impact of a 'sugar tax'. Whilst the study does not have access to individual brands cost pricing to retailers – it is able through the taxonomy and the EPOS data, to follow the way the SDIL impacted market retail pricing. The study reviews how much of the SDIL was passed through to shoppers on the brands who choose not to reformulate and hence became liable for the SDIL. The analysis shows that the tax was at least fully passed through, with a combination of some actual over-shifting and some significant mix effects at a category, brand and pack size level which can create *an illusion of over-shifting*. The analysis shows that consumers responded by reducing their consumption of levied drinks by around 18%, indicative of an inelastic response, especially in the drink-now and energy segments of the market. The analysis also reviews changes in the pricing of brands who were either exempt, or had reformulated to avoid the levy and then further considers substitution into diet drinks versions as a response to SDIL based retail price increases on the non-reformulated variants.

Whilst there is a short conclusion at the end of each chapter, there is a more detailed and discursive overall conclusion at the end of the thesis. This final section pulls together the main pricing threads in each of the chapters:

i) It looks forward to consider the future development of price endings in the FMCG market and the role of personalised pricing based on enhanced data analytical capability.

ii) After a short review of some of the more recent UK SDIL research published *post* the data period covered in this study, it also looks forward to consider how some of the findings of this thesis could impact future sugar tax decision making by producers, retailers, consumers and perhaps more importantly global regulators considering the development or introduction of such a policy.

The SDIL has arguably been one of the most successful health policy interventions ever introduced by a UK Government. Hence, understanding why this is the case is crucial to other global regulators seeking similar policy impact, not only in soft drinks but also for other

categories where products create externalities or are considered to be high in fat, salt and sugar (HFSS).

Before moving into the specific chapters, there is one final section to this introduction which provides a brief overview of the UK Soft Drinks market and the data available to analyse the key dynamics. This market and data background section provides an important foundation for the rest of the thesis.

Introduction to the UK Soft Drinks Market and EPOS Data

The UK Soft Drinks market was estimated to be worth circa £20bn at retail value in 2023 which equates to a UK spend of some £295 per capita. According to Kantar the soft drinks category is purchased by some 99.4% of all households[7] - in short it is a category that the vast majority of people make purchase decisions about on a day in day out basis.

A list published by The Grocer magazine in 2022 of the 'Top 100 UK Grocery Brands' contains some 19 soft drinks brands, by far the largest category represented in the list. Furthermore, a third of the top 15 UK grocery brands are soft drinks, namely the global brands Coca Cola, Pepsi, Red Bull and Monster, and the more domestic UK brand Lucozade.

The grocery stores who sell these brands range from hypermarkets to small convenience stores and from high end luxury retailers through to more value orientated discounters. One thing all these stores tend to have in common is an Electronic Point of Sale (EPOS) system. Each individual scan (signified by a beep) of each individual item's barcode sees the sales value and volume centrally recorded. This data is purchased from or shared by the retailers with global data analytics companies such as Nielsen and Circana, who check the robustness of the data and then (on a commercial basis) provide access to the data to retailers and producers. Throughout the period of my study A.G. Barr have purchased their UK soft drinks grocery market EPOS data from Circana. I am very grateful that both AG Barr and Circana kindly agreed that this EPOS data could be freely used for this thesis, subject to certain conditions.[8]

Soft drinks are also present in sales channels outside of core grocery stores. Of the circa £20bn of consumer spend on soft drinks in 2023 some £3bn came through foodservice, for example buying a soft drink at a café in the University, and £4.6bn through the licensed trade for example buying a soft drink in the pub next to the University (Britvic, 2023). Whilst combined these channels represents circa 40% of the retail value of the soft drinks market they represent less than 10% of the market volume. This reflects the price paid per serving in different channels. In the grocery channel in 2023 the average price paid for a litre of Cola was £1.42, in the licensed trade it was £6.25 (Circana 2025). The lack of consistent EPOS systems and

[7] Kantar (2023) – household penetration of soft drinks taken from the main Kantar panel.
[8] The key condition was that no data would be presented in the public domain on a retailer specific basis and that brand level data would only be identified where it could not be considered as commercially sensitive.

established chains across both foodservice and licensed outlets means the data available (provided by more specialist companies) tends to be more indicative than the high-quality data available from retail outlets.

Whichever the sales channel, the key objective of any brand owner is to secure distribution of their products. Being distributed, or 'securing a listing' means the product is physically available for the drinker to purchase. In 1923 Robert W. Woodruff became President of The Coca Cola company and coined an expression which is as relevant today as it was a hundred years ago and sums up the importance of distribution. He talked about the importance of Coca Cola being "within an arm's reach of desire" (FT, 2015).

Coca Cola is a great example of a well distributed product - being sold in deep distribution (the vast majority of stores and outlets) across all the channels where soft drinks are sold. For example, the EPOS data used in this study records that in 2023 in UK Grocery of the 57,124 stores selling soft drinks some 55,663 sold Coca-Cola or one of the variants (Circana 2025).

Key to understanding the dynamics within the UK soft drinks market is the concept of segmentation. The overall market can be broken down into a number of groupings to aid understanding. The first and most important of these taxonomies is category or sub-category.

Often the easiest way to define a soft drink category or sub-category, is to view the market from a shopper perspective, something which can be simply done by looking up at the aisle descriptors in a large supermarket. These will use shopper friendly terms to indicate in which aisle you will find categories such as Fizzy Drinks, Squash, Water or Fruit Juice.

The soft drinks industry also uses its own unique set of acronyms and descriptors. There are 'catch-all' descriptors such as OFCs which stands for 'other flavour carbonates' or any fizzy drinks which can't be described as a cola, lemonade, mixer or energy drink. The key soft drinks categories and sub-categories and their associated sales volumes are shown in Table 0.1.

Table 0.1: UK Soft Drinks - category breakdown by volume (litres)

Market Data - EPOS (IRI) = UK Grocery market	Volume Litres - Year to Aug 2014	Volume Litres - Year to Aug 2023	Index	% Split 2014	% Split 2023
Total Soft Drinks	**7,769,993,218**	**8,019,253,721**	**103**	**100%**	**100%**
Total Cola	1,869,636,192	1,936,688,764	104	24%	24%
Total OFC	808,290,760	945,519,907	117	10%	12%
Total Lemonade	369,608,734	302,801,806	82	5%	4%
Total Sports & Energy	627,173,480	833,561,186	133	8%	10%
Total Mixers	190,184,502	184,216,852	97	2%	2%
Total Carbs	**3,864,893,667**	**4,202,788,515**	**109**	**50%**	**52%**
Total Fruit Drinks	565,962,420	446,309,784	79	7%	6%
Total Fruit Juice + Smoothies	781,355,298	567,541,870	73	10%	7%
Total Dairy	145,137,817	217,745,551	150	2%	3%
Total Water	1,975,330,562	2,228,360,830	113	25%	28%
Total Squash	437,313,453	356,507,171	82	6%	4%
Total Still	**3,905,099,551**	**3,816,465,206**	**98**	**50%**	**48%**

Table 0.1 shows the change in volume (litres) of soft drinks from a base year of 52 weeks through to August 2014, across the following decade through to August 2023. Cola and Water (bottled) remain the highest volume categories with Dairy, Sports and Energy and OFC's showing the strongest volume growth - whilst Lemonade, Fruit Juice, Squash[9] and Fruit Drinks are in decline. The table also provides an aggregate for Carbs (fizzy) and Still drinks. The other key shopper measure is £'s spent as shown in Table 0.2.

Table 0.2: UK Soft Drinks - category breakdown by value (£)

Market Data - EPOS (IRI) = UK Grocery market	Value £ - Year to Aug 2014	Value £ - Year to Aug 2023	Index	% Split 2014	% Split 2023
Total Soft Drinks	**£8,073,469,304**	**£11,763,075,383**	**146**	**100%**	**100%**
Total Cola	£1,790,826,882	£2,745,190,023	153	22%	23%
Total OFC	£808,137,425	£1,334,463,718	165	10%	11%
Total Lemonade	£162,130,192	£173,126,406	107	2%	1%
Total Sports & Energy	£1,271,391,246	£2,461,625,559	194	16%	21%
Total Mixers	£150,311,690	£278,839,538	186	2%	2%
Total Carbs	**£4,182,797,435**	**£6,993,245,244**	**167**	**52%**	**59%**
Total Fruit Drinks	£814,655,773	£881,686,170	108	10%	7%
Total Fruit Juice + Smoothies	£1,142,834,703	£1,142,329,469	100	14%	10%
Total Dairy	£328,429,433	£713,759,189	217	4%	6%
Total Water	£1,080,216,104	£1,500,250,822	139	13%	13%
Total Squash	£524,535,856	£531,804,488	101	6%	5%
Total Still	**£3,890,671,869**	**£4,769,830,139**	**123**	**48%**	**41%**

Whilst overall soft drink volumes were only 3% higher across the decade, value in £ spent

[9] It is important to understand whether squash is being reported as sold (hence undiluted) or as drunk. Whilst these introductory tables present squash as sold, for all the SDIL consumption and calorie analysis it will be calculated as consumed using the recommended dilution ratio.

increased by some 46% - a CAGR of 4.3%. Adjusting for the modest volume growth the average £ per litre paid increases from £1.04 to £1.47 or a CAGR of 3.9% - marginally ahead of the average UK CPI rate of 3.5% over this timeframe (ONS 2023).

One of the key factors in any analysis of an FMCG market are the many pricing mix effects that can occur between categories, brands or even pack formats within brands. A mix effect is created when the overall average price per litre (ppl) increases because of a change in the ratio of sales (or mix) from each of the individual sub categories, each of which has a different average £/pence per litre (£/PPL) sold. These differences in the £PL will be particularly relevant in chapter 3 as we review the pass-through rate of the SDIL (Table 0.3).

Table 0.3: UK Soft Drinks - category average £ per litre 2014 - 2023

Market Data - EPOS (IRI) = UK Grocery market	£ per Litre - Year to Aug 2014	£ per Litre - Year to Aug 2023	Index
Total Soft Drinks	**1.04**	**1.47**	**141**
Total Cola	0.96	1.42	148
Total OFC	1.00	1.41	141
Total Lemonade	0.44	0.57	130
Total Sports & Energy	2.03	2.95	146
Total Mixers	0.79	1.51	192
Total Carbs	**1.08**	**1.66**	**154**
Total Fruit Drinks	1.44	1.98	137
Total Fruit Juice + Smoothies	1.46	2.01	138
Total Dairy	2.26	3.28	145
Total Water	0.55	0.67	123
Total Squash	1.20	1.49	124
Total Still	**1.00**	**1.25**	**125**

As the data above shows the average £ per litre varies significantly by category. The two fastest volume growth categories (Dairy and Sports & Energy) also have the highest £ per litre pricing - which provides a significant positive mix effect to the average £ per litre and overall value growth in the category. An example of this would be the long-term growth in energy drink purchasing at the expense of more traditional categories such as cola. As each new cohort of consumers enters the market with energy representing a higher share of their requirements, the sports and energy category (at £2.95 pl) increases volumes at the expense of the cola category (at £1.47 pl). This creates a mechanical increase in the average total soft drink retail £ per litre.

Finally - one of the most helpful ways to think about a category is from an average consumer or per capita perspective as shown in Table 0.4 – a methodology which can be applied to volume (share of requirements, or sometimes called share of throat) or value (share of spend).

Table 0.4: UK Soft Drinks - category per capita consumption and spend levels

Market Data - EPOS (IRI) = UK Grocery market	Per Cap Litres - Year to Aug 2014	Per Cap Litres - Year to Aug 2023	Index	Per Cap £ - Year to Aug 2014	Per Cap £ - Year to Aug 2023	Index
Total Soft Drinks	**120.3**	**117.7**	**98**	**£124.98**	**£172.63**	**138**
Total Cola	28.9	28.4	98	£27.72	£40.29	145
Total OFC	12.5	13.9	111	£12.51	£19.58	157
Total Lemonade	5.7	4.4	78	£2.51	£2.54	101
Total Sports & Energy	9.7	12.2	126	£19.68	£36.13	184
Total Mixers	2.9	2.7	92	£2.33	£4.09	176
Total Carbs	**59.8**	**61.7**	**103**	**£64.75**	**£102.63**	**159**
Total Fruit Drinks	8.8	6.5	75	£12.61	£12.94	103
Total Fruit Juice + Smoothies	12.1	8.3	69	£17.69	£16.76	95
Total Dairy	2.2	3.2	142	£5.08	£10.47	206
Total Water	30.6	32.7	107	£16.72	£22.02	132
Total Squash	6.8	5.2	77	£8.12	£7.80	96
Total Still	**60.5**	**56.0**	**93**	**£60.23**	**£70.00**	**116**

The per capita calculation is based on the ONS population mid-point estimate of 64.6m UK residents in 2014 vs 68.1m in 2023. It shows consumption levels down 2% across the timeframe with the average per capita spend on Soft Drinks in UK Grocery stores increasing to just over £172.

Other key taxonomies referred to in this thesis include:

Purchase Occasion:

Take-home - purchased in a store and consumed at home.

Drink-now - purchased in a store or outlet for immediate or 'on the go' consumption

Served Drink - purchased in an outlet and served in a glass

Packaging Type and Size:

Can - a metal can sold either as a single or a multipack – typically 250ml – 330ml or 500ml

PET Bottle - plastic bottle sold in a variety of sizes from 150ml – 3000ml

Glass Bottle - a glass bottle which equates to more premium packaging – variety of sizes

Carton/Pouch - a paper or plastic based packaging format such as a Tetra pack – variety of sizes

Calorie Content / Ingredient Functionality:

Regular - used to refer to a soft drink with sugar added, historically at circa 10grams per 100ml

Diet - used to refer to a drink variant where the sugar has been replaced by sweeteners.

Chapter 1:

A Penny More or a Penny Less

Left-Digit Bias and Consumer Purchase Behaviour.

1.0 Introduction to the Chapter

In his seminal work 'Principles of Economics' (1890), Alfred Marshall used the analogy of a pair of scissors to describe the interaction of supply and demand. This powerful analogy argues it is not possible to say which 'blade does the cutting', simply that both are required to determine the quantity and price. The Marshallian cross is the foundation of standard demand theory where the consumer (Homo Economicus) makes rational choices at any given price point in a ceteris paribus environment. In this neoclassical world, as the price of any given good falls then the quantity demanded increases. Price elasticities are deemed to reflect a smooth and continuous demand curve with the rational consumer reacting to a 1p fall in price from £10.00 to £9.99 in a very similar way to their reaction to a 1p fall from £9.99 to £9.98.

Behavioural research into price endings seeks to build on these core foundations and to offer stronger empirical explanations for consumer behaviour. This chapter focuses on the concept of left digit bias and its most common manifestation through the practice of 'pricing in the 9's'.

New research into both the presence and effectiveness of left digit bias through 9 endings has been published consistently throughout each and every decade of the past century. Initial investigation tended to approach the use of 9 ending price points from a marketing or psychology perspective, however in the past 50 years the concept has been embraced by behavioural economists as an example of how the laws of demand can be impacted by 'irrational' consumers and their use of heuristics in decision making. Arguably busy supermarket aisles, where the average purchase decision takes place in just 12 seconds (UK Food Standards Agency 2023), are ripe for the study of intuitive, heuristic based type 1 thinking vs. more calculated and deliberate type 2 thinking (Kahneman, 2011).

When it comes to the setting of retail pricing, a large UK supermarket will carry as many as 20,000 individual lines or SKUs (stock keeping units), the majority of which will sell for less than £5[10] and all of which need their own specific price point. Even a convenience store will require as many as 5,000 individual price points to be set (Association of UK Convenience Stores 2023).

[10] The pricing survey of the top 100 brands showed that 85% of observed price points were < £5

This study makes use of Electronic Point of Sales (EPOS) scanning data[11] which provides the most comprehensive read of the UK Grocery market. Each time an individual item is scanned through a checkout, either by an assistant or the shopper themselves, it emits a 'beep' to confirm the sale has been recorded. As referenced earlier, the aggregate number of 'beeps' in the year to w/e 22nd Feb 2025 was some *59,813,523,870* or some 2,100 items per UK household (Circana 2025). Hence a single penny difference on each of these beeps, with no assumed impact on demand, equates to some £600,000,000 of additional retail turnover or £21 per UK household. Whilst the value of a single penny is now so de minimis most people wouldn't stop to pick one up from the pavement - the sheer number of individual units sold in UK grocery stores supports the old proverb, 'if you take care of the pennies then the pounds will look after themselves'. In short, research into left digit bias and the applied pricing strategy of pricing in the 9's can be considered just as impactful and relevant today as it was a century ago.

The concept of left digit bias is very simple and is based on people (shoppers) displaying a perception bias towards the leftmost digits in any given number and a tendency to consistently disregard either partially or completely the numbers to the right. In practice, this means that when shoppers see a 'just below' number they do not mentally round up, but round down. When presented with a £3.99 price point, shoppers do not add on the penny to read £4.00 – but use a heuristic which reads the £3 first digit, and then places limited consciousness on the £0.99 element of the number. The same concept would apply if an item was for sale at £399 – the focus is on the £300 rather than the £99 which accounts for just under a quarter of the final purchase price.

The basis for the concept is the difference between Type (System) 1 and Type (System) 2 thinking (Kahneman, 2011). Research consistently shows that most grocery shopping purchases are made quickly, intuitively and automatically (Kalnikaite, et al., 2012). This approach is consistent with Type 1 thinking, where shoppers find it easier to simply process the first number in any given price point. The alternative, Type 2 thinking carries a higher mental processing cost and slower more deliberate calculations. If there was an advertising strapline for the left digit bias heuristic it might well be 'why bother processing three digits when one will do?'

[11] Data provided to AG Barr plc by Circana. The data is purchased by AG Barr for commercial reasons and has kindly been shared free of charge to support this study.

With perhaps the exception of a busy grocery store, high-street shopping for many is a pleasurable activity which induces the brain to release the chemical dopamine (Hartson, 2012). Hence, there is a further argument that shoppers use left digit bias to self-justify purchases, in effect employing a form of optimism bias to read and process the lowest number possible. Even within grocery stores the past 30 years has seen significant growth in sales of the more dopamine releasing 'non-food' items. Discounters such as Lidl and Aldi sell a diverse and ever-changing range of 'non-food' items in the middle of their stores, whilst large hypermarkets devote an increasing amount of floorspace to items such as clothes, electrical, garden equipment and books.[12]

The concept of left digit bias extends far beyond the shelves of supermarkets, with research finding clear evidence of 'just below digits' impacting value perceptions in a diverse range of circumstances. For example, in the used cars market, milometer levels at just below 10,000 mile thresholds and to a lesser degree 1,000 mile intervals create significant points of discontinuity in wholesale pricing (Lacetera, et al., 2012). An extra 100 miles covered driving a car to the auction will be very costly for the seller if they increase the milometer from 49,950 to a reading of 50,050 miles. In the housing market, auctions for high value apartments were shown to be more competitive when the starting prices were set at just below key price point thresholds (Repetto & Solis, 2017). The left digit bias effect encouraged more competition with more bidders and bids, resulting in final selling prices some 3-5% ahead of those listed at or above key price point thresholds. Even in financial markets with professional traders there is clear transactional based evidence of left digit bias with excess selling (and hence buying) at stock price points one penny below round numbers (Bhattacharya, et al., 2011).

A further significant question for both researchers and practitioners is whether the left digit bias response of shoppers is both consistent and homogenous or does it vary based on some psychological or demographic segmentation? There are a number of studies which have considered this specific question, with Baumgartner and Steiner (2007) initially finding that one group of consumers exhibited a more positive purchase response towards nine endings than another group, which in contrast showed a stronger preference towards zero endings. However, sample limitations within the two groups meant that the study was unable to statistically link any specific attributes to each response. Building on this work, Gaston-Bretton (2011) improved both the sample diversity and size robustness to show that the preference for 9

[12] Circana – non-food sales in food retailers now account for 25% of total sales.

endings was to be found in younger consumers, and typically those with lower educational achievements and income levels. Two further studies in 2015 validated this research with Kumar and Pandey (2015) identifying the same demographic preferences, whilst Wilkie et al. (2015) focussed on the segment who exhibited a preference for 0 endings and found it to be skewed towards older consumers with higher income levels.

Each of these studies also considers the link between price-ending, consumer segmentation and quality perception. A consistent theme is that 9 endings signal 'discount and value' and hence work better on lower priced, functional every day purchases (such as grocery shopping) than on higher priced premium items where the consumer is more emotionally invested in the purchase. However, Fraccaro et al. (2021) argue that odd pricing, for example pricing a luxury item at £1,495 compared to £1,500 is still the dominant market preference in prestige goods with the £5 acting as a 'guilt relief' mechanism for the consumer.

This study is focussed on the more functional market for consumer packaged goods; those items that get placed frequently into shopping trolleys and baskets. It considers the price points shoppers encounter in supermarket and convenience stores during the monthly, weekly or often daily shop. A summary of the existing literature shows clear historical evidence of the practice of retailers pricing in the 9's:

Table 1.1 The % of Price points ending in 9 - Summary of Literature Findings

Price Point Endings	% at 9		% at 5		% at 0
(Twedt, 1965)	65%		19%		1%
(Friedman, 1967)	34%		N/A		N/A
(Kreul, 1982)	58%		35%		0%
(Schindler & Kirby, 1997)	31%		19%		27%
(Stiving & Winer, 1997)	36% - 51%		N/A		N/A
(DellaVigna & Gentzkow, 2019)	78%		N/A		N/A
(Snir & Levy, 2021)	40% - 95%		N/A		N/A
(Strulov-Shlain, 2023)	61%		N/A		N/A

Notes: This table shows the % of price endings recorded in various studies covering the past 50+ years. Where the % is presented as a range this typically accounts for observations across different categories within the store.

Most research finds evidence of both the practice and its positive effect on demand. Of the articles cited only Knauth (1949) asserts that whilst the policy is 'in vogue', experiments have indicated that the policy fails to have *any* effect on the rate of sale:

"Customers do not distinguish materially between $4.95 and $5.00, and $4.95 does not suggest $4.00".

Knauth's research, in the middle of the 20th century, would not have had access to store scanner or EPOS data. Blattberg & Wisniewski (1987) produced one of the first studies to evaluate the specific impact of 9 ending price promotions using EPOS data and concluded that 9 endings delivered a 10% uplift when compared to promotions ending in other digits. Little & Ginese (1987) were able to use similar EPOS data with a logit model to identify positive price ending effects and consumer preferences for pancake syrups with price points ending in the number 9. Mace (2012) recognises that the research into pricing in the 9's has shown a clear effect on sales but calls out the variability in the results and focuses on understanding the determinants of success surrounding 9 ending pricing, specifically, the influence of the brand, category, store fascia and the demographics surrounding the store. The paper concludes that:

"a wide and indiscriminate practice of nine-ending pricing is not effective"

and highlights premium brands where the practice may be counter-productive. However, in low price categories or on small brands the paper concludes that significant benefit can be gained from a 9 ending pricing strategy with the analysis showing sales increases of 9.8% to 23.7%. Finally, Ortega & Tabares (2023) highlight the debate surrounding left digit bias through the choice of title of their study "Psychological pricing: Myth or Reality?" Using two categories as diverse as Kitchen Towels and Mobile Phones they run lab-based experiments to conclude there is a left digit effect, but as per Mace (2012) the extent is dependent on the category and the context.

The most compelling research on left digit bias, and arguably the most relevant to this thesis is advanced by two recent studies, based on access to i) high quality US grocery EPOS (scanner) data (Strulov-Shlain, 2023) and ii) disruptive digital technology (List, et al., 2023). Both of these studies provide compelling evidence of the presence of left digit bias and advocate harnessing the power of this behavioural effect to maximise the profit delivery by the firm. Strulov-Shlain (2023), analyses scanner data for 3500 products sold across 25 US retail chains using a structural model to calculate that retailers underestimate the power of the bias. In so

doing the study concludes that retailers forgo *1% – 4% of potential profits*. List et al. (2023) are able to access data from the ride sharing app Lyft and through a combination of observing some 600m Lyft sessions and the ability to then run field experiments with 21m passengers, validate large discontinuities in demand around the dollar value, concluding that additional profit of circa $160m is available to the firm through the adoption of a left digit pricing strategy.

Given the strength of findings in these two studies, and the overall weight of extensive research into price point endings, the first question asked in this chapter is a very obvious and pragmatic one:

"Do the largest grocery retailers in the UK actually embrace the concept of left digit bias and deploy pricing in the 9's as a live pricing strategy?"

The 3 largest UK grocery retailers are Tesco, Sainsbury's and Asda, who between them account for over half of all UK grocery spend (Kantar 2023). Tesco and Sainsbury's are long established FTSE listed plc's with both private and institutional shareholders, whilst Asda is a private limited company. On an aggregated basis these retailers reported some £3.7bn of operating profit in 2023 / 2024 and it is a fair assumption that they put significant effort into optimising their pricing strategies to maximise their total shareholder returns. Yet this chapter will show that contrary to the findings of both historical and recently published research and contrary to the popular belief that 9 and 99 ending price points are ubiquitous in retailing, the reality is that the leading UK grocery retailers, are actively looking to avoid the use of 9 ending price points. *In stark contrast to the summary presented in Table 1.1, this study will show that only 1.8% of all price point endings in the Top 100 UK grocery brands in the top 3 largest UK retailers ended in the number 9.* In the discussion we will consider why this might be the case and why the considerable evidence of over half a century of research is, very consciously, not being put into practice.

One of the other common misconceptions amongst shoppers is that the retail prices they pay are set by the brand owners themselves. This is not the case: retail price points are always set by retailers, except in the convenience channel in the UK where there is an extensive use of Price Marked Packs (PMP's), a specific situation where the brand owner effectively takes on the responsibility of setting the recommended retail price by printing a specific price point on the actual physical packaging. The second question this study asks is:

"Do brand owners themselves make more extensive use of 9 ending price points, in contrast to retailers?"

The answer to this question is undoubtedly yes – with *18 times as many price points set by brand owners ending in the digit 9 compared to their three largest customers.*

Finally, this chapter advances knowledge by considering the specific question:

"Would a retailer or a brand owner maximise sales volumes and revenues by selling a given product at 99p, or should they add 1p more and move to the 0 ending £1 price point?"

This final question is considered through a combination of access to high quality EPOS data at both an aggregated channel and store specific level, coupled with a natural experiment that was created when the popular UK soft drink brand IRN-BRU moved their PMP level from 99p to a £1 ahead of changes in competitors' PMP's. Two different DiD methodologies find no evidence of any negative impact on demand through the implementation of the 1p increase.

1.1 Data

A large UK retail outlet will carry up to 20,000 individual SKUs[13] with each identified by a unique product barcode (UPC). The analysis in this paper focusses on the shelf-price endings of the top 100 UK grocery brands[14] which account for some £30bn of grocery market shopper spend in 2022 and circa 15% of all the items priced in the store. The number of lines or SKUs sold under each of the Top 100 brands varies from 7 (Evian) to over 200 (Heinz) with the average number of SKUs per brand per store being just over 31. A full list of the brands is included in Appendix 1.

The retail shelf price point for each of these individual SKUs was recorded in November 2023, based on a combination of physical store visits and on-line shopping observations. It is important to note that it is not possible to calculate the actual shelf price point from aggregated EPOS sales by simply dividing £ total value by the total number of units sold. Whilst this would be significantly easier to do so than visiting stores, a number of factors can make the average unit selling price differ from the shelf price including variable shopper participation rates in multibuy promotional activity[15], the use of targeted loyalty card promotions or the purchase of product bundles such as lunchtime meal deals. Hence the requirement to record the actual price points displayed on the physical shelf edge labels.

The data is based on the largest stores (Supermarkets and Hypermarkets) of Tesco, Sainsbury's Asda and Morrisons and in total some 12,540 individual prices were recorded with perhaps not surprisingly the four retailers stocking a similar number of SKUs across the top 100 brands : Tesco (2,887), Asda (3,359), Sainsbury's (3,201) and Morrisons (3,093).

Data was also recorded for Aldi and Lidl. The operating model of these stores is very different from the domestic UK retailers as they present a more homogenous store size, with the core offering being based on the use of euro display pallets for the best-selling lines and a significantly reduced range count within the store. Whilst these retailers do stock some of the top 100 brands, in a number of cases they also substitute their own proposition in place of the

[13] Tesco IGD Briefing 2024

[14] Top 100 Brands as reported in The Grocer magazine for the 52 week period ending 31/12/22 and based on Nielsen IQ data (EPOS based data).

[15] For example, a retail price point of £1 could be overlaid with a 3 for £2 promotion. If half the shoppers buy into promotion whilst the other half just buy a single unit, the average price per unit sold will be recorded as £0.75 or ¾'s of the actual retail price point.

leading brand. Where this was observed the price ending of the equivalent Aldi or Lidl proposition was recorded. The total number of price point observations was 547 in Aldi and 570 in Lidl.

The rest of the UK Grocery market share is held by a number of smaller supermarket chains and then also spread across the circa 34,000 Symbol and Independent (S&I) stores that operate in the UK. S&I stores are typically owned and operated by a single individual or family. Whilst they are normally smaller convenience stores, many of the owners have invested in EPOS scanning systems to drive operational efficiencies. As per the larger chains the EPOS data from a number of these stores is collected and validated by data companies such as Nielsen and Circana to give an aggregated national representative read. There is also a specialist EPOS provider in the UK, The Retail Data Partnership Ltd (RDP) which provides S&I retailers across the UK with 'Shopmate' a ready-made EPOS solution for their stores. RDP helps owners install the necessary EPOS technology but also ensures that the barcodes and product descriptors are kept up to date via a centrally held database, a factor that drives a level of data accuracy consistent with robust academic enquiry.

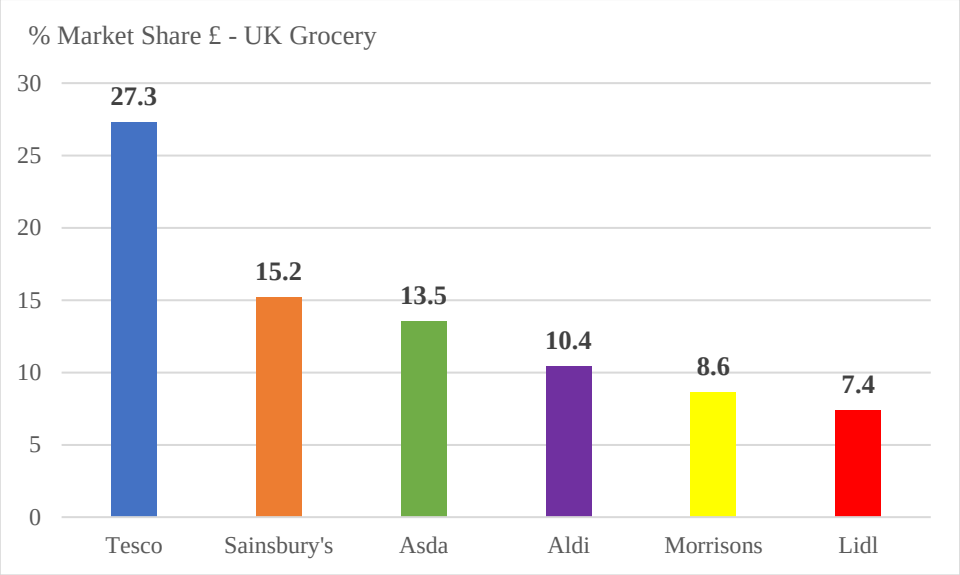
The main difference between accessing S&I EPOS scanning data from Circana compared to RDP is that whilst Circana gives a representative read of 34,000 stores it is only available at an aggregated S&I store (and hence channel) level. RDP gives a read of a smaller number of S&I stores (4,000 Shopmate users) but can provide access to store specific data. This paper utilises both of these rich data sources with access being granted by a combination of AG Barr, Circana and RDP Ltd to support this research.[16] The main variables of interest were the weekly unit sales of 500ml carbonate brands (number of bottles sold) and the price charged per bottle.

[16] AG Barr purchases Circana EPOS data for commercial purposes and both companies have granted access to the data. AG Barr also purchases RDP data for commercial purposes but this specific dataset of store level data has kindly been provided by RDP free of charge to support this research.

1.2 Background

The UK Grocery Market is dominated by six main retailers who between them account for over 82% of all consumer spend as shown in Figure 1[17]:

Figure 1.1 Kantar Worldpanel UK Grocery Market Share November 2023



Notes: This figure shows the market share % (based on £ spend) across the top 6 retailers in the UK Grocery Market in Q4 2023. The data is collected via the Kantar Household Panel and is shared on the public domain on the Kantar website.

The retailers split into two clear groups, the largely domestic UK founded Tesco, Sainsbury's, Asda and Morrisons who account for positions 1,2,3 and 5, and the global German founded discounters Aldi and Lidl, who have seen strong market share growth in the UK over the past 30 years to hold positions 4 and 6 respectively. Some 56% of the overall grocery share sits with the 'big 3' (Tesco, Sainsbury's and Asda) who operate some 5,500 supermarkets and convenience stores under their respective facias in the UK.

Whilst the UK consists of four devolved nations, each retailer prices on a UK wide basis deploying the same uniform shelf pricing across all the supermarkets within their estate regardless of location[18]. On pure economic grounds the optimal profit maximisation pricing model would flex local shelf prices to reflect regional specific features of demand such as the relative level of local competition and the variable equity strength of regional brands. The

[17] Source: Kantar Worldpanel Data Q3 - 2023

[18] There are only two exceptions to this, the first is that some of these retailers charge a convenience premium in their smallest stores – but do so on a consistent basis across the UK. Secondly the BWS (Beer, Wines and Spirit) category in Scotland is subject to MUP (Minimum Unit Pricing) which sets a minimum retail price point of 65p per unit of alcohol. This can lead to a differential between Scotland and the rest of the UK on some specific alcohol-containing products.

rationale for retailers not taking this approach is twofold. Firstly, any mass shopper awareness of a retailer flexing prices on a regional basis (specifically charging more one region more than another) will generate significant negativity amongst existing and potential shoppers which is likely to more than negate the profit benefit of differentiated prices. Secondly, region specific pricing can also create operational issues. An example of this is the growth in on-line shopping; for every £7 being spent on groceries in Tesco, £1 of this is now being spent on-line (Tesco 2024 IGD Briefing). This creates a challenge as to whether Tesco should base their regional pricing on the point of order or the point of delivery, and if it was the latter how would they avoid the negative PR associated with what would inevitably be called 'postcode pricing'? Hence the price of any given stock keeping unit (SKU) will be the same in a Tesco Supermarket in Aberdeen as in Aberystwyth and Aldershot.

As set-out in the introduction one of the common misconceptions by consumers (and researchers) is that brand owners are responsible for setting the retail shelf price and hence the price endings. The brand owner is only responsible for setting a cost price, and within UK consumer packaged goods (and in most FMCG markets around the world) it is the retailer who is responsible for both the overall pricing strategy and the final retail price point chosen on each individual product they sell. Any action from a brand owner to fix or unduly influence prices between retailers would be considered anti-competitive and would in all likelihood result in an investigation from the competition authorities.[19]

Hence with circa 34,000 individual owner decision makers, the S&I store channel would normally be considered one of the most challenging places to look for consistency in retail pricing on any given SKU. However, the extensive use of Priced Marked Packs (PMP) in the S&I channel creates a unique opportunity for researchers to analyse price endings and the impact they have on demand. A PMP is where the brand owner physically prints the price on the pack as part of the packaging artwork and hence effectively has control over the price point presented to the shopper. This is clearly dependent on the S&I retailer choosing to sell a PMP rather than the equivalent plain pack which has exactly the same artwork but no price printed on the container. The use of these packs is unique to the S&I channel where it offers two main benefits to the retailer. The first is that it removes the labour costs involved in printing shelf edge labels or physically stickering packs at the point they are placed on the shelf. The second

[19] In 2008 the OFT - Office of Fair Trading, investigated potential price fixing by UK supermarkets and its leading suppliers via what they termed A-B-C information flows. This is where supermarket A would communicate its pricing intentions with supermarket C via supplier B. The investigation was closed in 2010 owing to "administration priorities" with no action taken.

is that it helps communicate value for money to the shopper – *'I am selling this pack to you at exactly the recommended price the brand owner believes it should be sold at'.*

Analysis of the EPOS data shows that the adoption of PMP's in this channel is widespread. For example, if we consider Red Bull 250ml, a key selling line in S&I stores and look at the EPOS data for December 2021 it shows some 33,781 (almost every S&I store) selling the pack. Of these some 27,504 stores had chosen to sell the £1.35 PMP variant (and were doing so at the PMP level) with the remaining 6,277 choosing to sell the plain pack version at an average retail price of £1.56.[20] The store owner's decision to be a PMP vs plain pack retailer tends to be binary and once made is typically consistent across all the brands offered in the store. From a data perspective PMP provides both the stability and the opportunity to analyse natural experiments caused by retail ending price moves at the point of a PMP transition. Even in an inflationary environment these tend to be limited to 1 or 2 price moves a year as there is a significant process cost (artwork, stock management and customer communication) involved in changing a PMP price point.

This research exploits a specific PMP transition of a single penny (1p) that occurred in December 2021 when the popular and iconic soft drink IRN-BRU increased its price from £0.99 to £1. The visual representation of this change is shown in the two bottles in Figure 1.2 with the highlighted 99p price mark (printed at the top of the label in red on a yellow background) simply moving to show £1.

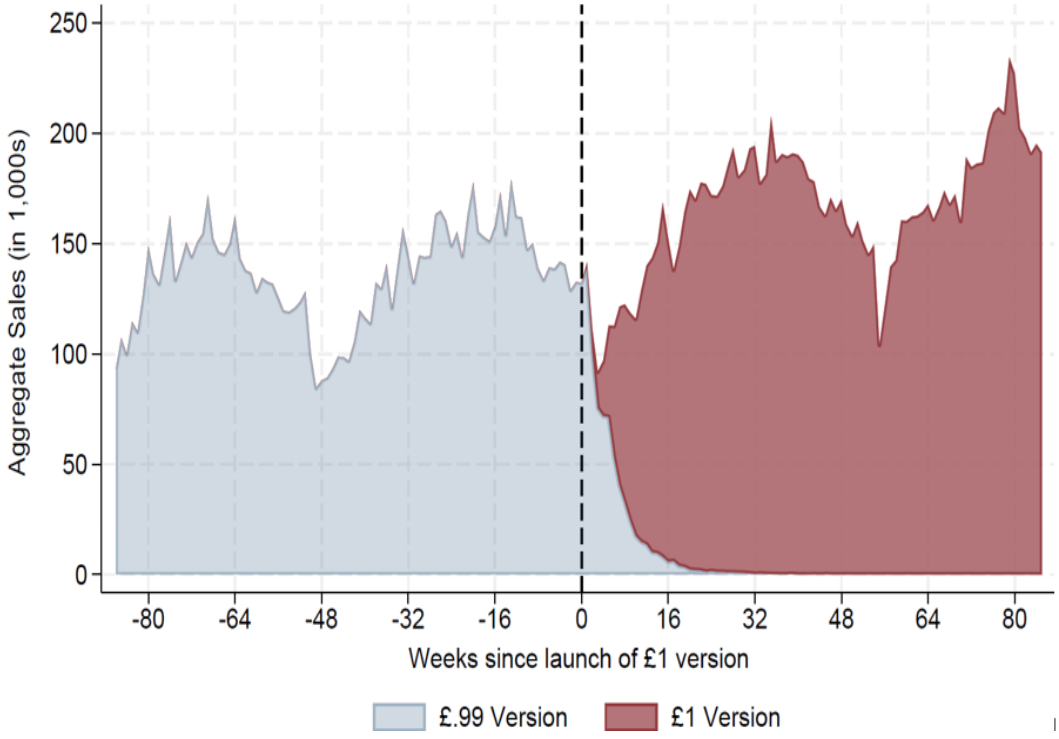
Figure 1.2 IRN-BRU 500ml Priced Marked Pack (PMP) 99p to £1 Increase

Notes: Spot the difference - the only physical differences between the two packs are the front-of-pack printed price-mark (99p to £1) and a new barcode on the back-of-pack to correspond with the new price point when scanned at the checkout.

[20] Source: Circana S&I EPOS data Red Bull 250 ml Regular Single Can w/c 18th Dec 2021

The graphical representation of this transition is shown in Figure 1.3 which shows that the average sales of the product of interest varies between 100,000 and 150,000 bottles per week. The area chart shows the split of sales between the £0.99 PMP and the £1 PMP with the new £1 pack (the treatment effect) being introduced during week ending the 11th December 2021. There is a clear transition period of about 20 weeks during which both types of labels are in circulation in the market. After the first 6 weeks, sales of the new £1 PMP outstrip those of the replaced £0.99 PMP.

Figure 1.3 IRN-BRU 500ml PMP transition from 99p to £1



Notes: Week 0 corresponds to week ending 11th December 2021 and shows the start of the run-out period of the 99p pack and introduction of the new £1 pack.

Aggregate sales of both types of bottles ostensibly drop sharply (by about a quarter compared to the previous run rate) within two weeks of the introduction of the £1 version. However, this decrease in sales is almost certainly due to seasonal factors. Drink-now 500ml bottle sales consistently fall at the turn of the year owing to the Christmas season and its combination of holidays (from school and work) and cold weather – all of which have a negative impact on demand. Figure 1.3 also shows similarly sized changes in sales around the turn of the year in 2020/21 as well as 2022/23 and this is consistent with the rest of the 500ml market. Indeed, considering these seasonal fluctuations, Figure 1.3 shows little indication that the change from £0.99 to £1 depressed sales. If anything, there is suggestive evidence of a slight uplift in sales

in the long run which provides some initial support for the hypothesis that the 1p increase had no negative impact on shopper demand.

In order to better account for seasonal influences and to pursue a more robust analytical approach, further Circana EPOS data was obtained. Nationally representative convenience and independent store sales data was collected not just on IRN-BRU 500ml bottle sales, but for the equivalent 500ml bottle sales of 21 other leading mainstream carbonate brands / sub-brands who would be considered the closest competitors for IRN-BRU.

There are a number of ways of defining whether a brand is a close competitor. Arguably the easiest heuristic for the consumer is the simple proximity of the items on the shelf or fixture. To help shoppers in their purchase decisions retailers naturally cluster different brands and products into a physical group of close competitors. For example, when you stand and look at a chiller in a convenience store, the 500ml bottles of fizzy carbonates are typically grouped together, as are the bottles of water, bottles of fruit juice, or energy drink cans. Secondly, there are very specific brand features, such as flavour or sugar profile, carbonation levels, functional or health benefits, which create a natural competitor set. Thirdly, price acts as a signal to consumers of close competition and it is noticeable that the PMP's observed across the 22 brands fit within a relatively narrow £0.99 - £1.29 range. In contrast 500ml bottles of water would sit grouped below this level, whereas 500ml cans of energy drinks would sit above it. Finally, there are specific brand tests to identify close competitors. These include research which asks the consumer to select an initial purchase from the fixture, then physically or visually removing that choice and asking them to make a further purchase. In formal competition analysis this methodology forms the calculation basis of any gross upwards pricing pressure indices (GUPPI), a methodology that is often used in submissions to the competition authorities.

The objective is to compare sales changes in IRN-BRU (that changed price) to those of the comparison brands (that didn't). Collectively, IRN-BRU and the 21 other brands / sub-brands are representative of the vast majority of the UK carbonates market, accounting for some 83% of total carbonate sales and 89% of all 500ml carbonated bottle sales in the S&I channel.

Table 1.2 lists the 21 brands / sub-brands and shows their average weekly sales and their PMP price point in the 27 weeks leading up to the IRN-BRU price change. The table also details the exact date when the PMP increases started to appear in the market on each of the competitor

brands. These were in the range of 5p to 11p a bottle and hence effectively marks the point at which the common time trend assumption within the control group starts to breakdown.

Table 1.2 List of Competitor Brands, original PMP price point / start of transition

Brand - PMP 500ml	Average Weekly Sales	OLD PMP Pricepoint	NEW PMP Pricepoint	Week of First Price Change
IRN-BRU	152,491	£0.99	£1.00	10-Dec-21
Coke Zero	131,468	£1.00	£1.05	12-Feb-22
Coca Cola	503,307	£1.29	£1.39	19-Feb-22
Diet Coke	246,079	£1.09	£1.15	19-Feb-22
Cherry Coke Zero	40,485	£1.00	£1.05	19-Feb-22
Vanilla Coke Zero	24,870	£1.00	£1.05	26-Feb-22
Dr Pepper	243,233	£1.09	£1.09	05-Mar-22
Sprite	60,473	£1.00	£1.05	05-Mar-22
Fanta Zero	32,246	£1.09	£1.15	12-Mar-22
Dr Pepper Zero	55,281	£1.09	£1.15	19-Mar-22
Pepsi Max Cherry	143,511	£1.00	£1.09	02-Apr-22
Pepsi Max	274,437	£1.00	£1.09	02-Apr-22
Diet Pepsi	68,932	£1.00	£1.09	09-Apr-22
7up Sugar Free	30,082	£1.00	£1.09	09-Apr-22
Pepsi Max Respberry	33,279	£1.00	£1.09	09-Apr-22
Pepsi	118,551	£1.15	£1.25	16-Apr-22
Tango	37,059	£1.00	£1.09	23-Apr-22
7up	28,670	£1.00	£1.09	23-Apr-22
Fanta Fruit Twist	133,607	£1.09	£1.15	n.a.
Fanta	141,611	£1.09	£1.15	n.a.
Cherry Coke	159,110	£1.29	£1.39	n.a.
Vimto	52,192	£1.00	£1.00	n.a.

Notes: Average Weekly Sales refers to the period from week ending 5th June 2021 (beginning of sample) to week ending on 3rd December 2011 (the week before the IRN-BRU price change).

One complication in comparing the treatment brand, IRN-BRU, with the set of control brands is that they are close substitutes for one another. In particular, it is highly probable that price changes in one brand may affect sales in the other brands, not least because the price points are very salient for PMP's with the bottles sitting next to each other on the chiller shelf. For this reason, a time period was identified during which there were no PMP price changes for any of the comparison brands. This was the case between the week ending on 5th June 2021 and the week ending on 19th February 2022 at which point Coca Cola Zero 500ml was the first comparative brand to introduce a new PMP (increasing from £1 to £1.05). Hence, there is a 27-week pre-period leading up to the IRN-BRU price change of interest during which none of

the comparison brands change their own pricing and a 9-week follow-up period during which none of the comparison brands made any changes. The following section (1.2) outlines how this supports a difference-in-differences analysis that uses across-brand variation.

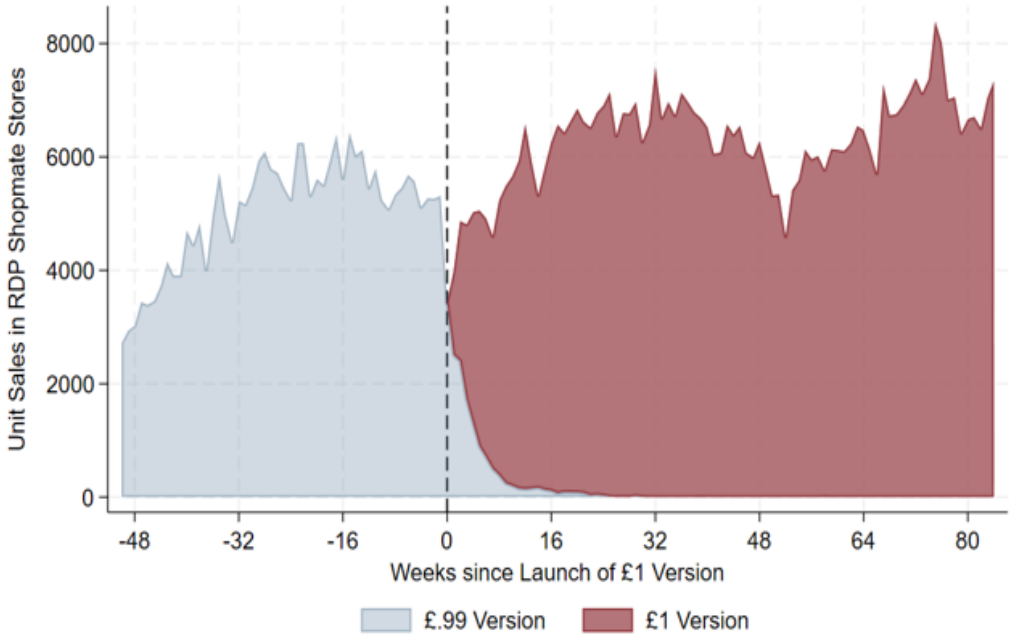
Secondly, store-specific sales data was obtained from RDP for a different, difference-in-differences analysis that uses across-store variation with again the detailed methodology for this approach set-out in the following section (1.2). From a background perspective it is important to understand how natural variation in timing (the new PMP pack appearing on shelf for the first time) occurs. The key operational point is the diligence with which S&I store owners manage their stock, both ensuring they carry some safety stock (either in depth on the shelf or in a storeroom) and the practice of ensuring old stock is sold through first before new stock is placed on the shelf. Shelves are filled from the back with the older stocked faced up at the front to avoid the costly risk of products going out of date before they are sold[21]. In terms of a PMP transition, this means that stores that happen to sit on a stock of bottles with the original price will have to run through this stock first before being able to put bottles with a new price onto the shelves. Hence even though all the IRN-BRU 500ml bottles shipped from AG Barr to their customers during the week ending on December 11th 2021, and from then onwards, were printed with the new £1 price, this new PMP would hit the shelves earlier in some S&I stores than in others. The RDP Shopmate EPOS data provides weekly sales by store for each of the IRN-BRU 500ml packs and hence makes it possible to track each of the transition points and specifically when the new £1 is first sold in any given store.

It is important to note that this store-specific information is only available for a subset of convenience stores that have purchased the Shopmate EPOS system from RDP. However, Figure 1.4 suggests that these stores are fully representative of the overall market read[22] (of which they are also a part). Indeed, aggregate sales from the RDP stores in Figure 1.4 and the total S&I EPOS store sales in Figure 1.3 exhibit all but identical sales trends and seasonal patterns.

[21] All perishable goods sold in the UK require a best before date (BBD) which dictates the shelf life of the product. 500ml bottles typically have between 6 and 12 months shelf life at point of production. Whilst this time period is longer than some other categories in the store – the practice of selling through older stock first (product with the soonest BBD) is an ingrained practise in independent stores where the actual owners feel the cost of any write-offs personally.

[22] Whilst the stores are anonymised, the individual postcodes are provided. This allows a check to be run which confirms cross UK regional representation within the RDP data.

Figure 1.4 IRN-BRU 500ml PMP transition from 99p to £1 in RDP Stores



Notes: Figure 1.4 which is an aggregation of the RDP data essentially follows the same sales trend as the full channel Circana data shown in Figure 1.3. Week 0 again refers to week ending 11th December 2021 and it identifies the week when the transition from 99p to £1 PMP on IRN-BRU 500ml commences.

1.3 Empirical Methodology – Difference in Differences Analysis of PMP

The IRN-BRU 500ml PMP increase from 99p to £1 is analysed using two different, DiD analyses to the two different, but linked EPOS data sources, namely Circana the provider of the aggregated store data and RDP the provider of the store specific data.

1.3A Methodology of the cross-brand approach

Firstly, using the aggregated EPOS data we exploit the timing of the IRN-BRU change being some 9 weeks ahead of the start of the price changes of the 500ml PMP competition. This timing difference allows us to compare changes in sales of IRN-BRU 500ml before and after the price change with changes in the comparison brands during the same time period before they themselves change their price. As discussed in section 2, we have 27 weeks of data before the IRN-BRU price change without any changes in competitor pricing followed by 9 weeks of unconfounded post-period data.

We estimate a differences-in-differences model that is represented by the following regression equation:

$$(Log)Unitsales_{bt} = \beta_0 + \beta_1 NewPrice_{bt} + \sum_{b=1}^{22} \gamma_b Brand_b + \sum_{24/2021}^{8/2022} \delta_t Week_t + \varepsilon_{bt} \qquad (1)$$

Our outcome of interest is the log of unit sales of brand *b* during week *t*. We regress this outcome on a set of brand fixed effects and weekly fixed effects. The brand fixed effects account for any differences between brands in terms of brand owner, type of beverage, sugar content, flavour, colour, or any other product-specific characteristic. Specifically, the effect of price which is fixed for each brand in both the 27-week pre- and 9-week post-periods, and thus time-invariant, is accounted for. Weekly fixed effects control for any time-variant effects that affect all brands simultaneously. For instance, changes in temperature and weather conditions are significant factors in the level of consumer demand for soft drinks, and specifically for 500ml bottles which are sold chilled for immediate consumption, but neither need to be included into our analysis of national sales data because our time fixed effects capture the aggregate effect. A log specification is used for the analysis of the outcome variable as it both supports a simpler graphical comparison between the sales of IRN-BRU and an aggregation of all other brands, whilst also presenting the impact of change in PMP regression results in Table 1.7 in percentage terms.

The coefficient of interest is $\beta_1$which measures the treatment effect of the brand's decision to move the PMP on IRN-BRU from £0.99 to £1 on unit sales. $NewPrice_{bt}$is a dummy indicator that is 1 for those IRN-BRU observations that date to after the price change, and is zero for all other sample observations. Given the dependent variable is in logs, β_1 can be interpreted as the percentage before-after change in IRN-BRU sales relative to the change in comparison products.

The main identifying assumption in our model is that IRN-BRU 500ml sales and those of our comparison brands would have followed similar trajectories in the absence of the price change (the common time trend assumption). Figure 1.6 provides compelling evidence that this assumption is indeed met. Furthermore, the approach requires that consumers are unable to anticipate and react to the coming price change (the no anticipation assumption). Purchases of chilled drink-now 500ml bottles are made on the go for immediate consumption hence consumers typically will not stock up even if they were aware of a significant change in price coming. This pre-awareness in itself is highly unlikely, brand owners do not advertise price increases and typically the first time the consumer will see the new £1 pricing on the bottle is when they stand in front of the chiller and make their purchase choice. Even if the consumer was aware of the change coming and had the means to stock up, it is doubtful that knowledge of a 1p / 1% rise would be sufficient motivation to do so.

Finally, we require an absence of any spill-over effects (the stable unit treatment value assumption or SUTVA). Because any price changes on competitor brands may jeopardize this assumption, we limit our post-period to the 9 weeks during which none of our comparison brands changed their price e.g. none of the new PMP levels detailed in Table 1.2 appeared in the market. As a robustness check, we extend this follow-up period to 12 and 15 weeks, respectively, but remove any of the 21 brands that experience price changes during each respective period from our sample. Of course, it is still possible that the IRN-BRU price increase stimulates demand for competitor products. However, note that the direction of any such bias would lead us to over-estimate any sales-reducing effect of the price change.

1.3B Methodology of the cross-store approach

For the second differences-in-differences approach we use the store specific EPOS data set and exploit differences in the time at which the new £1 IRN-BRU 500ml version became available in different stores. In the grocery multiples, pricing is controlled centrally and can be changed on a daily basis throughout the store estate.[23] This is not the case for PMP's in the Symbol and Independent channel where there is naturally a far more staggered transition of old bottle to new bottle and hence staggered price change to the shopper.

The key factor that influences the actual transition date is the level of stock in both the store and the wholesale route to market used by the store owner. Store owners have different sized stock rooms, visit their wholesaler (cash and carry) with different levels of frequency and have different attitudes to carrying safety stock[24]. Likewise, the wholesalers, from whom the store owners will source their stock will themselves carry different stock levels based on size of depot and whether the product is delivered frequently from an intermediate central distribution centre to the depot or directly by the brand owner to the depot where often the logistical terms encourage the depot to take less frequent deliveries of full truckloads (and hence high stocks) to maximise delivery efficiency.[25]

Both of these factors create quasi-random variation in the timing on which the new PMP bottles reach the actual shelves and hence when the shopper is exposed to the new price point. As stated in the previous background section (1.1) store owners sell through their older dated stock first, in this case of £0.99 priced bottles, before putting the new £1 marked bottles onto their shelves generating this exogenous variation in the adoption of the new price.

This methodology compares the change in unit sales in stores that happen to introduce the £1 early on to the change in unit sales in control stores that have yet to make the transition. The late-switching stores act as a control group for early-switching stores. Because we are again comparing differences-in-differences, the effects of any national or seasonal trends that affect both types of stores are accounted for. For example, both early and late-switching stores are likely to experience higher sales during good weather in the summer.

[23] Some supermarket chains now use electronic shelf edge labels allowing shelf prices to be changed in near real time.

[24] Attitude of the store owner to running out of a particular line and losing a sale by disappointing one of their shoppers.

[25] The two largest Cash and Carry groups in the UK run markedly different value chains with one asking suppliers to deliver centrally into two large distribution centres and the other asking suppliers to deliver directly into the 65 depots they operate.

The same identifying assumptions as in the cross-brand analysis apply. That is, the common-time trend assumption requires that early and late-adopting stores follow similar trajectories over time – for which we will provide clear evidence in the results section. As it is the manufacturer who makes pricing decisions and prints the label, the assumption of "no anticipation" is also likely met. Finally, our stores are spread across the UK, thus further diminishing the already small odds that a 1p change in one store may have a direct spill-over effect on sales in another store in our sample, hence supporting the stable unit treatment value assumption.

It is important that this second DiD approach exploits a staggered series of changes, i.e. introduction of the £1 version into an "ever expanding" set of stores – rather than a one-off change as in the comparison across brands which underpins our first DiD approach. Recent econometric research shows that with dynamic and heterogeneous effects, a standard two-way fixed effects model may not produce valid estimates in a setting with a staggered rollout (de Chaisemartin & D'Haultfœuille, 2020), (Goodman-Bacon, 2021), (Callaway & Sant'Anna, 2021).

For our store level analysis, we therefore use the "interacted weighted" (IW) estimator developed by Sun & Abraham (2021). The IW estimator is designed to produce consistent event-study estimates for DiD design that exploit a staggered introduction – such as the setting where the £1 version was introduced in different stores in a staggered fashion.

The IW estimator estimates cohort specific average treatment effects, $CATT_{e,l}$where "e" is a group of stores that introduces the £1 in a specific week. In our setting we have 12 individual groups of stores with the first group selling the new version in the 52nd week of December 2021 and the final group in the 11th week of 2022. As mentioned above, we consider a store "treated" at the first point when its £1 version sales exceed those of the 99p version. "l" then refers to relative time since treatment" in weeks.

Intuitively, the IW estimator uses the last group of stores as control group and for each of the other treatment groups "e" and for each "l" obtains a $CATT_{e,l}$. These $CATT_{e,l}$are then aggregated for all pre-treatment lead-periods and post-treatment lag-periods. For this aggregation we use weights that correspond to the sample share of each group in a given "l". (Sun & Abraham, 2021) show that this approach yields consistent estimates even with heterogeneous treatment effects, as long as our standard identifying assumptions hold.

1.4 Results

1.4A Question 1 - Observed price point endings across UK Grocery Stores

"Do the largest grocery retailers in the UK embrace the behavioural concept of left digit bias and deploy pricing in the 9's as an active pricing strategy?"

We first present the results from our store survey and the overview of pricing patterns and strategy in the UK grocery market. Table 1.3 below shows the aggregated price endings observed for all Top 100 brand SKUs sold in the three largest UK retailers who represent some 56% of all UK Grocery spend. The observations were recorded in November 2023:

Table 1.3 Observed price point endings for each SKU sold - Top 100 Brands (Nov 23)

# Ending	TESCO	*TESCO*	SAINSBURY's	*SAINSBURY's*	ASDA	*ASDA*	TOTAL	*TOTAL*
0	1999	*69.2%*	2328	*72.7%*	2267	*67.5%*	6594	*69.8%*
1	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
2	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
3	0	*0.0%*	0	*0.0%*	1	*0.0%*	1	*0.0%*
4	0	*0.0%*	1	*0.0%*	5	*0.1%*	6	*0.1%*
5	806	*27.9%*	864	*27.0%*	990	*29.5%*	2660	*28.2%*
6	0	*0.0%*	0	*0.0%*	1	*0.0%*	1	*0.0%*
7	0	*0.0%*	0	*0.0%*	7	*0.2%*	7	*0.1%*
8	0	*0.0%*	0	*0.0%*	4	*0.1%*	4	*0.0%*
9	82	*2.8%*	8	*0.2%*	84	*2.5%*	174	*1.8%*
TOTAL	2887		3201		3359		9447	

Notes: This table shows the observed number of endings for each of the 10 possible digits across all skus sold belonging to brands in the Top 100. This is broken down for Tesco, Sainsbury's and Asda and then aggregated for these top 3 retailers. The %'s are recorded for each retailer and then at an aggregated level the % share of endings at each digit.

With only 1.8% of observed price points ending in a 9 the results are in stark contrast to the % of 9 endings recorded in the historical studies presented in Table 1.1.

Arguably the three largest retailers in UK Grocery are *actively looking to avoid* 9 endings with some 98% of endings finishing in a 0 or a 5. Furthermore Table 1.4 below shows the significant adoption of what might be termed as a quartile or 'tombola' pricing[26] strategy across the three largest UK retailers.

[26] In most Tombola's the best prizes are awarded to tickets ending in 00 - then 50 - and then to tickets ending in a 25 / 75.

Table 1.4 Observed number of price points ending in quartiles - Top 100 Brands (Nov 23)

Aggregated Tesco, Sainsburys, Asda Price Points		
£1	322	3%
£2	742	8%
£3	539	6%
£4	310	3%
£5	168	2%
All Round Pounds	**2580**	**27%**
£1.50	435	5%
£2.50	487	5%
£3.50	343	4%
£4.50	270	3%
All £.50	**1880**	**20%**
All £.25	875	9%
All £.75	691	7%
All quarter endings	**1566**	**17%**
TOTAL 25-50-75-00	**6026**	**64%**

Notes: This table aggregates the 25 – 50 – 75 - 00 price ending observations from Tesco, Sainsbury's and Asda.

This table shows that across Tesco, Sainsbury's and Asda just four of all possible price endings in any given £ are chosen nearly two-thirds of the time. The survey also shows the most common endings are £2, £3, £2.50 and £1.50 respectively.[27]

We can compare the price endings in the Top 3 UK grocery retailers with the next 3 largest retailers as measured by market share - namely Aldi, Morrisons and Lidl who hold a combined 26.4% of the market. Table 1.5 shows observed price point ending frequencies that are more consistent with the academic literature (Table 1.1):

Table 1.5 Observed price point endings for Top 100 Brands or equivalent (Nov 23)

# Ending	ALDI	*Aldi*	MORRISONS	*MORRISONS*	LIDL	*LIDL*	TOTAL	*TOTAL*
0	24	4.4%	1524	49.3%	0	0.0%	1548	*36.8%*
1	6	1.1%	0	0.0%	0	0.0%	6	*0.1%*
2	18	3.3%	0	0.0%	0	0.0%	18	*0.4%*
3	5	0.9%	3	0.1%	5	0.9%	13	*0.3%*
4	9	1.6%	1	0.0%	0	0.0%	10	*0.2%*
5	172	31.4%	854	27.6%	128	22.5%	1154	*27.4%*
6	3	0.5%	0	0.0%	3	0.5%	6	*0.1%*
7	11	2.0%	0	0.0%	0	0.0%	11	*0.3%*
8	21	3.8%	2	0.1%	2	0.4%	25	*0.6%*
9	278	50.8%	709	22.9%	432	75.8%	1419	*33.7%*
TOTAL	**547**		**3093**		**570**		**4210**	

Notes: This table shows the observed number of endings for each of the 10 possible digits across all skus sold belonging to brands in the Top 100. This is broken down for Aldi, Morrisons and Lidl and then aggregated for these 3 retailers

[27] These observations might also help explain the decline of the £1 store where every item is sold at £1.

Table 1.5 shows three distinct levels of adoption of 9 endings, with Aldi using them for half of all price points, Morrisons at circa a quarter and Lidl at circa three quarters. It is notable there is more extensive use of 9 endings in retailers who might be perceived more as 'challengers' and in the case of Aldi and Lidl often referred to as 'discounters'.

Arguably it is also these discounters more extensive use of 9 endings which accounts for the very limited use (1.8%) of 9 endings in the 3 largest retailers. Each of the 3 largest retailers advertises some form of Aldi / Lidl 'price match promise'[28] on a limited range of the top brands – as shown on Warburton's Toastie 400gm bread in Figure 1.5.

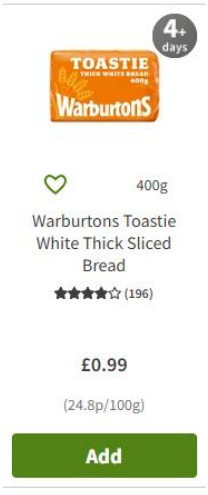
Figure 1.5 Tesco, Sainsbury's and Asda 'price match promises' resulting in 9 endings

Warburton's 400gm (#6 in Top 100 UK brand)

Tesco

Sainsbury's

Asda



Notes: These screenshots were taken from the on-line shopping website of each respective retailer in January 2024 and show the consistent use of a 99p price point and in the case of Tesco and Sainsbury's with a specific logo to call-out the price match with Aldi.

[28] Tesco (for example) promise that on certain lines they will watch and then match whatever the Aldi price point is to the exact penny – and this accounts for the very limited number of 9 endings observed in the retailer.

1.4B Question 2 - Observed PMP price point endings chosen by brand owners

"In contrast to the largest retailers, do brand owners themselves make more use of 9 ending prices when they choose their specific PMP price points?"

Table 1.6 shows the specific PMP endings chosen by the same Top 100 brand owners for sale through S&I stores. It is worthy of note that the range of pricing (18p to £5.99) is more limited than the range seen on plain pack in large supermarkets (15p to £22.85) which reflects the physical pack size of the item sold and the difference between a convenience basket shop and a supermarket trolley shop. It is also clear from the lower number of observations (881) that not every plain pack SKU or brand is being made available in a PMP equivalent.

Table 1.6 Top 100 Brands (or equivalent) price endings printed on PMP's (Nov 23)

# Ending		TOTAL	*TOTAL*
0		177	*20.1%*
1		0	*0.0%*
2		0	*0.0%*
3		1	*0.1%*
4		0	*0.0%*
5		377	*42.8%*
6		0	*0.0%*
7		0	*0.0%*
8		2	*0.2%*
9		324	*36.8%*
TOTAL		**881**	

Notes: The price endings on PMP's were observed through Nov 23 visits to Booker and Bestway, the two leading wholesalers in the UK, who supply S&I stores with a choice of booth PMP and plain pack items.

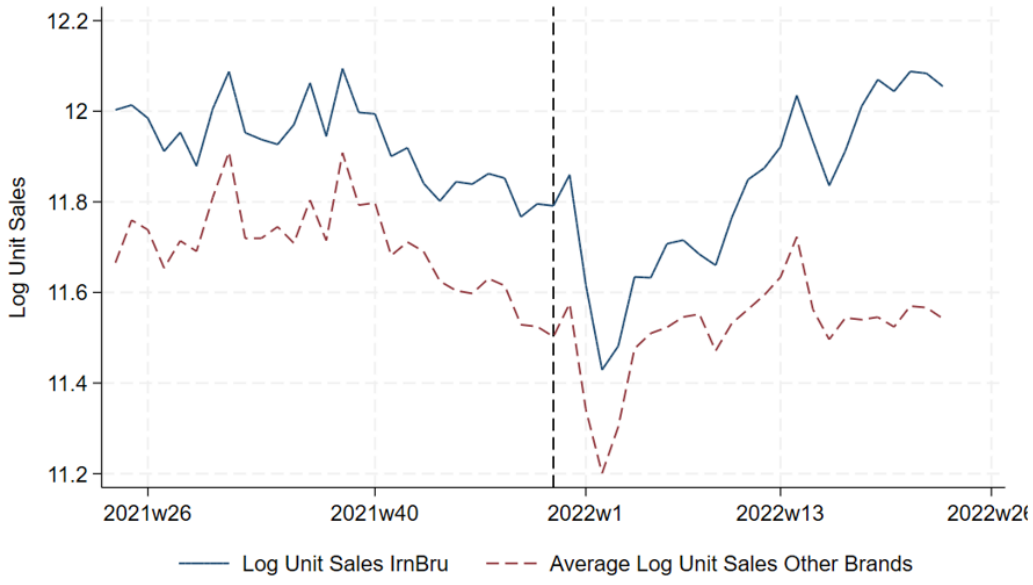
It is interesting to note that the actual brand owners themselves, when given the opportunity through PMP to set price endings, *make far more use of 9 endings (36.8%) than their 3 largest customers (1.8%).*

1.4C Question 3 - Cross Brand Difference in Differences Results

"Given a choice of selling a given product at either 99p or at a round £1, which price point should the sales maximising retailer (or in the case of PMP, brand owner) choose?

Having shown the perhaps counter-intuitive rareness of pricing in the nines in the UK grocery market, we next turn to our difference-in-differences analysis of the switch from a 99p ending to a full pound for 500ml bottles of IRN-BRU to understand the impact on sales of this change. We start with a descriptive cross-brand analysis. Figure 1.6 shows that sales of IRN-BRU 500ml PMP closely resembles those of the aggregated all other 500ml brands in our sample. Crucially, both the solid blue line showing the IRN-BRU sales and the dashed red line showing an average sales level for the close competitor control group follow all-but identical trajectories in the period pre-dating the IRN-BRU pricing change. This is comforting as identical time trends in the pre-period make the common time trend assumption underpinning the regression estimation very plausible.

Figure 1.6 (log) Weekly unit sales of IRN-BRU vs the Competitor control group



Notes: This chart which provides a comparison between Log IRN-BRU 500ml weekly unit sales, and an average Log unit sales of 21 competitor brands, shows clear graphical evidence of a common time trend assumption in the weeks leading up to the £1 pack being introduced and the first 9 weeks post the introduction. Figure 1.7 shows that the common time-trend assumption also holds when an absolute (rather than log) measure of sales is used.

Figure 1.7 provides a comparison between the absolute sales numbers for IRN-BRU 500ml PMP with the average sales of the other brand comparison products. IRN-BRU sales consistently follow a trend which is about 30,000 units or about 25% higher than those of our

average comparison product. Again, note that such a difference in levels does not invalidate our DiD approach as long as trends in sales are similar – an assumption that is supported for both logged and straight unit measures.

Figure 1.7 Absolute weekly unit sales IRN-BRU vs the Competitor control group

Notes: This figure provides a comparison between absolute unit sales of IRN-BRU 500ml weekly unit sales and the average weekly unit sales of 21 competitor brands. As per Figure 1.6 it also shows clear graphical evidence of a common time trend assumption in the weeks leading up to the £1 pack being introduced and the first 9 weeks post the introduction.

Both Figures 1.6 and 1.7 suggests that the unit sales did not disproportionately decrease for IRN-BRU after the new £1 PMP was introduced (the dotted horizontal line). Both treatment and comparison brands show a seasonal drop but recover quickly. For most of early 2022, both treatment and comparison trends continue in parallel, indicating that the new £1 price point had no effect on sales.

This is confirmed by the DiD regression analysis. Column (1) of Table 1.7 indicates that the price change led to an increase in IRN-BRU PMP sales of 0.98%. However, this estimate is not statistically significant and we cannot reject the null hypothesis of a zero effect at any reasonable significance level. Our estimate is also precisely estimated, such that we can rule out even a moderate 3% drop in unit sales with 95% confidence.

Table 1.7 Regression Results – Effect of change from 99p-£1 PMP on (log) unit sales

	(1)	(2)	(3)	(4)	(5)	(6)
	9 Weeks Post-Period		12 Weeks Post-Period		15 Weeks Post-Period	
Pricing Effect	0.0098	0.0095	-0.0036	-0.0028	-0.0075	-0.0031
	(0.0190)	(0.0202)	(0.0219)	(0.0249)	(0.0232)	(0.0260)
Specification	Full	Donut	Full	Donut	Full	Donut
Number of Brands	22	22	17	17	11	11
R^2	0.990	0.990	0.986	0.986	0.987	0.987
N	792	704	663	595	588	532

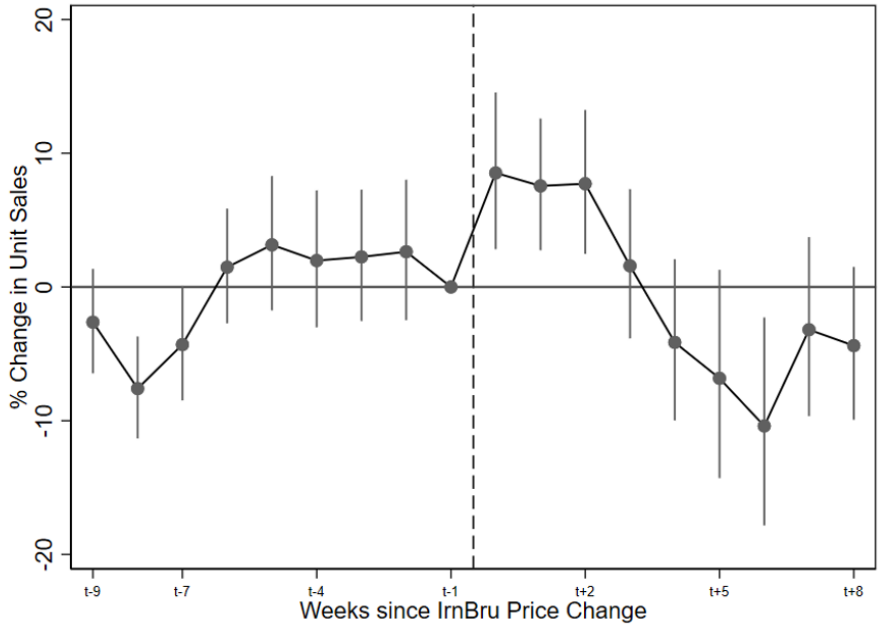
Notes: Heteroscedasticity-robust standard errors adjusted for clustering at the brand level. *p <0.05, **p <0.01, ***p 0.001. This table shows regression results of a DiD regression model as outlined in equation 1. Brand fixed-effects and week fixed-effects are included in all specifications. The unit of observation for this specification is the brand week, all data are unweighted.

Column (2) repeats our estimation but discards data from the four-week holiday period following the IRN-BRU price change. While Figures 1.6 and 1.7 show that both treatment and control group are affected similarly by this year-end period, it is comforting that our regression results are also robust to such a 'donut' specification that cuts out a time period during which sales are potentially more volatile.

In columns (3) to (6), we further vary our sample by extending the follow-up period to 12 and 15 weeks respectively. Of course, during these additional 3-6 weeks, some of the control brands themselves adjust the level of their PMP and hence need to be excluded from the sample to maintain an "uncontaminated" control group. That is, extending the follow-up period is a trade-off between including more weeks per brand into our analysis but simultaneously having to drop some brands. It is striking that neither approach qualitatively changes our result. We cannot reject the null hypothesis of no change in sales in either specification.

Figure 1.8 shows the results of an event-study version of the regression over the full transition period. Again, it is comforting that all lags leading up to the price change tend to hover around zero and are insignificant at any reasonable level of statistical significance. In the post-period our event-study estimates indicate a mix of relative increases and drops, although neither long-lasting or indicative of depressed sales.

Figure 1.8 Event-study version of the cross-brand regression



Notes: This figure provides the event-study estimation for the effect of the IRN-BRU price change from 99p to £1 on (log) unit sales relative to the comparison brands control group who did not experience a price change.

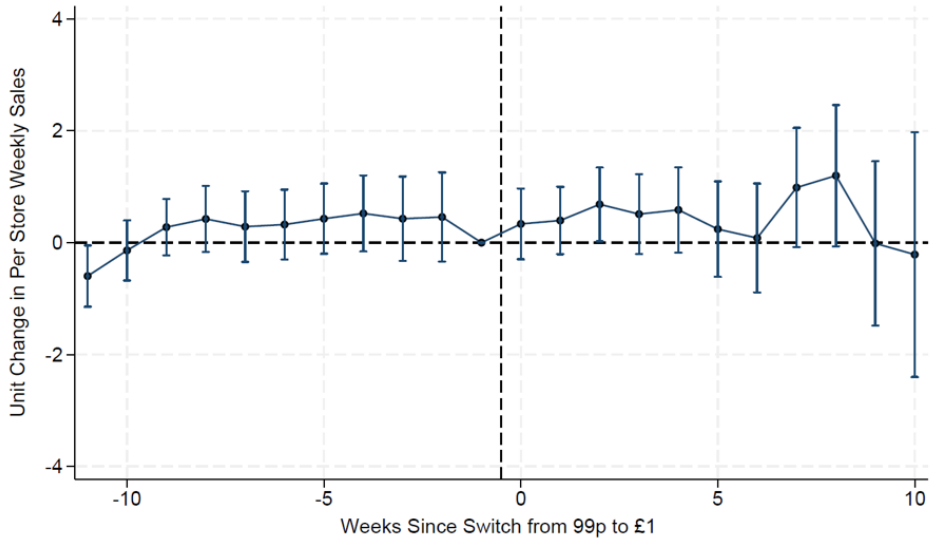
1.4D Question 3 - Cross-Store Difference in Differences Results

"Given a choice of selling a given product at either 99p or at a round £1, which price point should the sales maximising retailer (or in the case of PMP, brand owner) choose?

The same question, but this time answered using the DiD methodology as set-out in 3.2, where we switch from an aggregated cross brand control group, to the store specific sales data for the IRN-BRU packs.

The null result of our cross-brand analysis is further supported by this second DiD design that exploits differences in the time at which the new £1 version became available in different stores. The event plot in Figure 1.9 is constructed using the IW estimator developed by Sun and Abraham (2021) which is designed to analyse a staggered rollout and accounts for heterogeneous treatment effects. All leads hover around zero, none of them are statistically significantly different from zero at the 1% level, nor are they jointly statistically significant.

Figure 1.9 Event-study version of the cross-store regression



Notes: This figure provides the event-study estimation for the IRN-BRU price change from 99p to £1 exploiting the differences in store transition timings.

Second, the lag coefficient suggests that the pricing increase from 99p to £1 did not materially affect unit sales. If anything, the price increase led to an increase in sales. For example, the first lag suggests that in the week in which the new version was launched sales increased by around 0.25 bottles on average. However, this increase is not statistically significant and hence the finding that the 1p increase had no rather than a positive impact on sales. The same remains true some six weeks after the introduction of the new pack. The confidence intervals for the final lags are wide enough to allow for substantial negative effects, but this is driven by the fact that they are being calculated using fewer and fewer observations. Indeed, the final 11^{th} lag only contains observations from the first-treated group and the last-treated group of stores. A 12^{th} lag cannot be estimated as the last-treated control group gets treated 12 weeks after the first-treated group. In any case, it is unlikely that it would take a couple of months for a demand response to materialise.

In summary, neither a descriptive analysis, nor a regression analysis, indicate that the price switch from 99p to £1 had a detrimental impact on sales.

1.5 Discussion and Limitations

Firstly, this study provides a clear practitioner example of why a better understanding of the impact of specific price endings and left digit bias *really* matters to retailers and brand owners. If we take the IRN-BRU PMP DiD analysis, with some 10,000,000 x IRN-BRU 500ml PMP bottles sold each year, the finding that there is no impact on consumer demand from the additional 1p increase underscores some £100,000 of additional retail sales value each year going forward. All of this increase flows straight through to the shared profit in the value chain[29].

The value in this type of analysis is the risk mitigation it represents for a firm making such a pricing move (99p to £1), a move that is contrary to the both the academic research and the conventional thinking on pricing. Whilst the specific profit margins on IRN-BRU 500ml PMP are clearly commercially sensitive and can't be shared as part of this study, it would have only taken a relatively small drop in volumes (about 2%) for this 1p (circa 1%) PMP increase to decrease overall brand profitability.

This study also shows the three largest retailers in the UK are prepared to take the risk associated of actively avoiding 9 ending price points, even when their fast-growing competition (the German discounters Aldi and Lidl) use the digit 9 in 50% and 33% of price endings respectively.

How can retailers and brand owners better understand the risks associated with charging 1p more or 1p less? There are many different theories about where psychological pricing was first used, but the eponymous J.C. Penney is often credited with running early store cluster - field experiments to better understand the importance of 9 endings. These experiments formed the empirical basis for J.C. Penney employing a just below pricing strategy as a core part of its shopper proposition as the retailer expanded operations throughout the US in the first half of the 20th century.

J.C Penney also serves to highlight the risks associated with changing a long-held price ending practise that over many years has firmly established a set of reference points for shoppers. In 2012, the iconic retailer, as part of its new 'Fair and Square' pricing strategy moved away from

[29] This value chain benefit is divided 3 ways - with 20% VAT for the UK Government and the remainder split between the retailer and the brand owner.

99 endings to a new strategy which saw pricing rounded to the nearest dollar. It is interesting that this decision, taken by a new CEO, coincided with a significant sales slump and was abandoned within the year.[30]

So why, given the weight of academic research that supports left digit bias do the 3 largest UK Grocery retailers actively avoid price points ending in a 9? Is it simply as shown in the 99p to £1 PMP analysis that demand does not change so why forgo the 1p more?

The study proposes five possible reasons for the pricing strategies of the big 3 UK retailers. These 'potential explanations' are based on a combination of discussions with various executives in these retailers and personal experience of the UK Grocery market.

Firstly, as discussed pricing in the 9's is also referred to as 'psychological pricing', 'magic numbers' or 'charm pricing'. All of these descriptors tend to suggest some sleight of hand or some sort of pricing trick. Given the importance of trust in what is a long-term relationship between these retailers and their shopper base, there could well be a desire to avoid such an interpretation and to simply come across as transparent or honestly straightforward in the presented pricing strategy and such an aim is better served by pricing largely based on quartiles (25,50,75,00).

The extensive use of a 'tombola' pricing strategy also supports the second potential reason, which relates to the impact on shopping behaviours caused by the recent 'cost of living crisis' in the UK. Post Covid19, there was a global spike in inflationary pressures which saw UK food price inflation peak at 19.1% in March 2023, the highest level for 40 years[31]. This level of increase significantly outstripped shoppers' disposable income growth hence the term 'cost of living crisis' was coined by the media. Shoppers were faced with having to make a fixed, and often a physically cash restrained shopping budget go further. Whilst on face value this would lead to the argument that surely every 1p matters more, the practical reality is that it is far easier for a shopper to calculate and maximise what they buy with a single £10 or £20 note if the majority of price endings are round pounds or based on quartiles.

The third potential reason relates to the high levels of shopper loyalty card usage in UK Grocery retailing. 2025 sees the 30th anniversary of the launch of Tesco Clubcard, whilst Sainsbury's (Nectar), Asda (Rewards) and Morrisons (More) have all followed the Tesco lead and introduced loyalty shopping cards that were originally physical cards and are now available on

[30] Harvard Business Review – Memo to JC Penney : Execution is NOT strategy 2013
[31] Office for National Statistics

App based technology. This usage provides each of these retailers with significant data on their shoppers and their shopping habits. For example, in the case of Tesco from 30m UK households there are now some 23m Tesco Clubcard holders and participation rates (the share of £'s spent in the retailer where a Clubcard is presented) now sits at 82%.[32] Such high quality shopper data coupled with developing data analytical capabilities gives each of these retailers unparalleled insight into how their customers make decisions about what they buy, and undoubtedly helps inform the setting of an optimal pricing strategy to maximise shopper loyalty and profitability. We will explore this point further at the end of the thesis when we consider the future of UK grocery market price endings.

The fourth potential reason is the declining value of a penny and the impact inflation has had on average item pricing. As a rule of thumb, a single 1p is now worth a 10th of what it was worth 50 years ago and an 80th of its value 100 years ago (Office for National Statistics - ONS 2025). The 400 gram loaf of Warbutons bread, that was provided as a 99p price matched example in the results section of this study, would have cost circa 2.5d (the equivalent of 1.25 new pence) in 1925.[33] Perhaps in the UK Grocery market the use of 9 endings was more relevant to a time period when most goods sold had a price point between 9p and 99p. Prior to this, and also prior to decimalisation[34] the most common coinage would have been the ¼d (farthing), ½d (halfpenny) and 1d (penny). This naturally led to price points based on quarters – and it is arguable that the largest UK Grocery retailers have simply gone full circle back to pricing strategies based on quarters – but this time through 25p, 50p 75p and round pound endings.

The fifth and final explanation worthy of consideration is that whilst the value of all those 1p's has declined, retailers have found that the optimal pricing and profit maximisation strategy is simply not to hand back the 1p change but to bank their share of the £600m worth of pennies highlighted in the introduction.

It is through PMP's in S&I stores that brand owners can continue to analyse the impact of price endings, specifically during the current set of 500ml carbonated PMP's where some brand owners continue to use 9 endings, whilst others adopt a similar pricing strategy approach to the large retailers and use only 5's or 0's. It remains a channel where there is less pricing 'noise' from promotions or meal deals and the processing costs of changing artwork tends to drive

[32] The Grocer March 2025
[33] London Bread prices 1600 – 1950's
[34] Decimalisation was introduced into the UK in 1971

consistency with the setting of an annual PMP level for most brand owners. Clearly, one of the limitations of this study is that the methodologies are applied to a single brand in a single category, but the potential for new knowledge from the use of PMP data (both at an aggregated and single store level) and the methodology blueprint is presented for further studies to expand across a more diverse range of products and shopper categories.

The main finding of this study, supported by two different DiD methodologies, is that when considering setting a 99p PMP, it is better to charge 1p more as this provides a circa 1% increase in revenue with no impact on demand. Whilst this finding is clear it is important that consideration is given to potential limitations in each of the chosen methodologies. Despite the consistent null hypothesis found in each approach, the staggered methodology is a more robust identification strategy.

The main reason for this is the risk of spillover effects within the aggregated 500ml control group created in the cross branded approach. If a shopper enters a store on a hot day to purchase a chilled bottle of fizzy drink and they react negatively to a 1p increase in the price on their preferred brand (IRN-BRU), they are highly likely to buy a close substitute rather than leave the store both thirsty and empty handed. The closest substitute following a conscious decision to switch from IRN-BRU is likely to be a purchase from within the control group of competing 500ml PMP brands. This would clearly break the SUTVA assumption, namely that an increase in the price of IRN-BRU has no impact on sales within the control group. However, if this did occur and there was a mechanical increase in control group sales it would be reasonable to expect a negative DiD coefficient and hence positive cross price elasticities would work against finding a null effect.

Whilst a null effect was clearly found with the cross-brand approach, consideration was given to other suitable control groups. For example, data was collected for IRN-BRU 500ml plain pack sales in equivalent chain convenience stores. If the plain pack price on IRN-BRU and competing brands had remained constant in these retailers from December through to March this would have been created a very robust control group for the DiD approach on PMP. However, the timing of the equivalent IRN-BRU plain pack increase was in early January, only 3 weeks post the change of the IRN-BRU PMP, removing any possibility of using equivalent plain packs as a valid control group. Consideration was also given to 500ml water, potentially including it is a triple design approach where it could act as a third control group. However, whilst this would arguably help mitigate the risks of spillover effects (water is a poor substitute

for a consumer who wants to purchase a flavoured, fizzy drink), the average price of a 500ml bottle of water also increased right at the start of the new calendar year.

Hence the preferred option and motivation for securing the store level data to exploit the natural variation in the date the new £1 pack first appeared in store. To my knowledge this is the first time a staggered DiD approach has been used in conjunction with store specific EPOS data from independent retailers exploiting the natural variation in pack introduction. It serves as a blueprint for further pricing studies offering a more robust and arguably logical methodology for DiD analysis.

A further hypothesis is that despite the null findings, *the results as presented do not necessarily contradict the weight of literature of left digit bias*. The reason for this is that the move from 99p to £1 could arguably be considered as a special case of left 'digit' bias.

It is important to note the £0.99 is written as 99p on the bottle – whilst the £1.00 is written as a £1 (Figure 1.10).

Figure 1.10 PMP move from 99p to a £1 – representation on packaging

Notes: The printing on the IRN-BRU 500ml PMP shows a printed price move from 99p to £1 rather than to £1.00

This leads to the question whether the representation of the £1.00 in a single digit (£1) creates a different type of pricing discontinuity based on the number '99' moving to '1'?

The dropping of the additional pence or '.00' is increasingly common in restaurants and specifically the more expensive ones where chips with the main course are extra, and are listed underneath 'sides' with the number '5' beside them. There are many examples of price promotions where the concept of left digit bias is arguably strengthened by the pence being printed in a smaller font than the left most pound digit.

The actual physical representation of the price ending, the way the price point is presented is a really interesting area for future research. Whilst I had no empirical evidence to back up the decision, when the brand team produced new packaging on a small multipack of cans to support

a move from £2.79 to £3.00, that was initially printed £2.79 to £3.00 rather than £2.79 to £3, I insisted it was scrapped and re-printed. With hindsight it could have supported an interesting field experiment.

Future research would also be strengthened by including a much broader range of price points than the potential special case of 99p to £1. Prior to the start of my studies and before I was aware of the extensive body of left digit bias research, I arguably found out the hard way about the power of the concept. In January 2006, I took the decision to increase the PMP on a single can of IRN-BRU from 39p (where it had been for 5 years) to 42p which equates to a modest 7.7% increase. However, the resulting significant fall in sales on this can in 2006 (an elasticity of -3.2) was an unwelcome surprise, to the point that in Jan 2007 I took the unusual decision to reverse the pricing move and subsequently the sales levels recovered (Figure 1.11).

Figure 1.11 IRN-BRU 330ml PMP can price moves 2005 - 2011

	2005	2006	2007	2008	2009	2010	2011
PMP	*39p*	*42p*	*39p*	*39p*	*39p*	*45p*	*49p*
Average Cases per Week	22,826	17,431	21,327	25,143	28,573	22,230	22,766
Yr on Yr Price Increase		7.7%	7.7%			15.4%	8.9%
Yr on Yr Volume Delta		-23.6%	22.3%			-22.10%	2.40%
Elasticity		3.1	2.9			1.4	0.27

Notes: Source is A.G. Barr sales-out data taken from their BI system. PMP changes took place on an annual basis at the end of the calendar year.

By 2010 inflationary pressures meant there was a need to revisit the price point decision and this time the PMP pricing moved from 39p to 45p a 15.4% increase. The resulting % fall in demand was similar to that seen four years earlier but with the larger increase (6p vs 3p) in pricing the elasticity halved. Interestingly, the move in 2011 from 45p to 49p saw no impact on demand across the rest of the year.

Figure 1.11 is presented with the clear understanding it is descriptive, rather than empirical evidence, and there will undoubtedly be other causal factors (specifically competitors' own price point changes) impacting demand in each of the years. However, the overall narrative would seem to be (and felt like) a compelling case of left digit bias behaviour from IRN-BRU drinkers.

Recent PMP pricing moves have seen 500ml bottles move further away from the £1 price point with for example Coke Zero 500ml and Dr Pepper 500ml choosing £1.20 and £1.30 as their PMP price points respectively. (Bestway Wholesale depot observations Jan 2025). I retired from my executive role at A.G.Barr in October 2024, and one of the last pricing decisions I was required to take was to set the 2025 PMP on IRN-BRU 500ml. This decision probably best reflects my view of the left digit bias concept and it is shown in Figure 1.12.

Figure 1.12 IRN-BRU 500ml PMP 2025

Notes: Source A.G. Barr – IRN-BRU 500ml PMP for 2025.

1.6 Conclusion

One of the earliest papers on 9 ending price points and left digit bias was by Ginzberg (1936) where the word ‘perplexing’ is used to describe the analysis and interpretation of the results.

In the introduction two recent studies by Strulov-Shlain (2023) and List et al. (2023) were highlighted, both of which find clear evidence of left digit bias and present the case for how firms can use this insight to maximise profit. It is perhaps then ‘perplexing’ that in contrast to the weight of literature and the pricing observations of previous studies, the UK’s largest grocery retailers deploy a pricing strategy that actively avoids the use of 9 endings and which is based largely on quartiles (tombola pricing). In the discussion we set-out some thoughts and perspectives as to why, despite compelling evidence for retailers to embrace left digit bias, they have made the decision not to do so.

This study also shows that in contrast to the retailers the brand owners themselves, when given the opportunity to print specific price points on the pack are 18 times more likely to use a 9 ending. This leads to the question should the brand owner embrace the left digit bias concept or follow the largest retailers lead and actively avoid the use of 9 endings?

Two DiD studies using two different data sets and methodologies show that IRN-BRU 500ml saw no fall-off in sales associated with an increase from 99p to £1. Whilst the analysis shows that IRN-BRU was right to ask for the penny more, further research is required across a broader range of price points to confirm whether this should consistently be the case.

Chapter 2:

 [35]

Does a Spoonful of Sugar Tax Make the Calories Go Down?

Analysis of the UK SDIL, Focusing on the Supply-Side Response

[35] Copyright Channel 4 – Jamie's Sugar Rush

2.0 Introduction to the Chapter

This second chapter provides both an overview of the structure of the UK SDIL and existing literature on sugar taxes before focusing on the supply side response to the policy. As the analysis in this chapter will show, the effectiveness of the SDIL is rooted in its ability to incentivise reformulation by acting as a clear co-ordinating catalyst for soft drinks producers. Furthermore, the significant gap of some 2 years between announcement and policy implementation provided producers enough time for high-quality, consumer tested reformulation to take place. This analysis combines UK soft drinks market EPOS data with longitudinal nutritional information in a variety of event-study specifications to show that all but a few global soft drinks brands reduced their sugar content and hence avoided the significant potential cost increase represented by the SDIL. Furthermore, the study shows that this reformulation accounted for the substantive part of the circa 6,600 calories per capita reduction delivered through the policy with more than 80% of the reduction occurring due to the decisions and actions taken by brand owners and producers in the two-year period *between* announcement and the implementation date.

A DiD approach that exploits staggered treatment effect timings is a long established identification methodology in Econometrics. A number of seminal papers were published throughout the first decade of the 21st century using a standard TWFE approach (Autor 2003), (Stevenson & Wolfers 2006), (Beck et al. 2010). These papers all took a multiyear period (such as the 1970's to the 1990's) and utilised a staggered treatment effect to identify specific outcomes of interest that ranged from legal dismissal doctrines, domestic violence levels, income equality and suicide rates.

In essence it is this same base DiD methodology which is applied to this SDIL analysis, using both the standard TWFE approach and then incorporating the 2020 – 2022 'revolutionary developments' which serve to remove the risk of biased estimates that have recently been identified in the traditional pre 2020 approach.

In this analysis the treatment effect is the decision by the brand owner to reformulate to avoid the SDIL by moving to a sugar level < 5grams per 100ml. The nature of the SDIL announcement and the 2 year period prior to implementation created a natural window for brand owners to complete this reformulation. As this analysis will show this generated some 34 individual reformulation events idiosyncratically staggered between January 2017 and April 2018.

2.1 Sugar and Sweeteners and the UK Soft Drinks Market

There is a long history of the use of sugar, or those sugars found to naturally occur in ingredients such as fruit juice and honey, to add sweetness to soft drinks. The first recorded use of honey to add sweetness to lemonade was in a 12th century Egyptian treatise whilst a century later Saint Thomas Aquinas is credited with the invention of the fruit sweetened 'Dandelion and Burdock'. By the middle of the 18th century, sugar sweetened ginger beer was a staple drink of the British Army, the sugar helping to improve taste and provide energy whilst also acting as a natural preservative. Yet it is the end of the 20th century when the most recognisable global and domestic carbonated soft drink brands (Figure 2.1) were first launched.

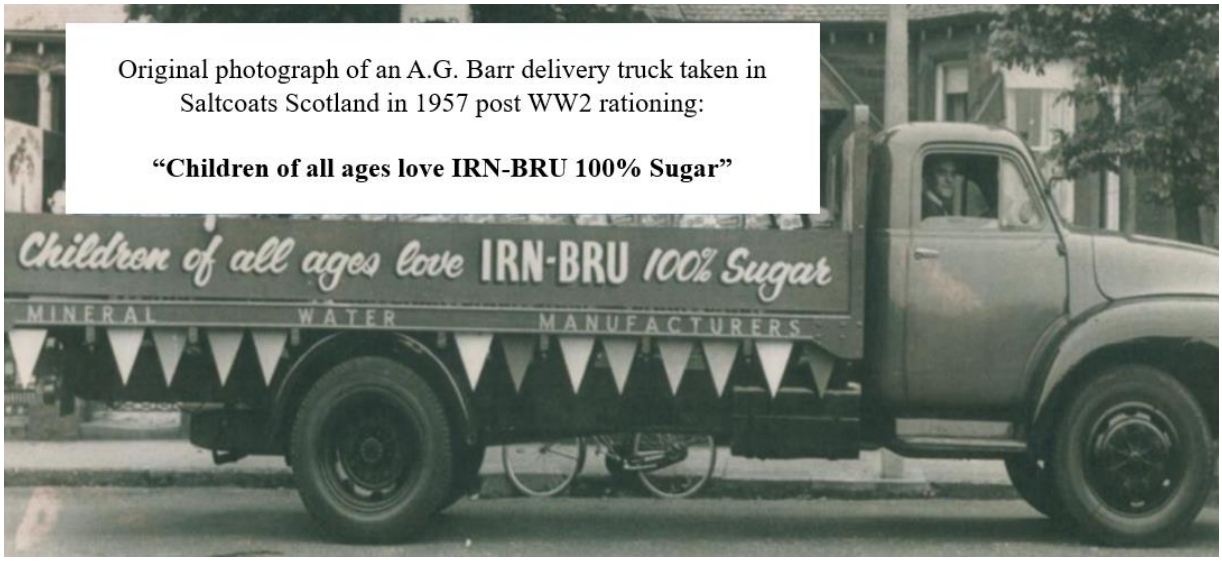
Figure 2.1 Key global and domestic carbonate brands with launch dates

Notes: Source is the respective brand websites, brand history section. It is interesting how close all the launch dates were to each other and also how close the original Pepsi logo was to the later established Coca-Cola logo.

Whilst the taste of these well-known brands clearly varies, at launch they all had one consistent ingredient and that was sugar (sucrose) which was extracted from raw cane, corn or beet and used to deliver a sweet tasting drink. Carbonated soft drinks also typically contained acid, either naturally occurring in the fruit content or added in the form of citric, malic or phosphoric acid. It is this acid which causes the sucrose to hydrolyse and to create glucose and fructose. In some markets glucose and fructose can be added directly to the drink – for example in the US most drinks are sweetened with High Fructose Corn Syrup (HFCS) rather than raw cane or beet derived sugar (Bray, et al., 2004).

All of these 'sugars' also provide a similar calorific content of circa 4 kcals per added gram. For the majority of sugar sweetened soft drinks throughout the 20th century some 10 – 11 grams of sugar would be added per 100ml of liquid to deliver the 'perfect sweetness'. Hence a 330ml serving of a 'sugared' soft drink would typically contain circa 35 grams of sugar (often presented as 8 teaspoons) which delivered some 140 calories. Throughout much of the 20th Century the use of sugar was seen and presented as a key product benefit – for example as shown in Figure 2.2, through the 1957 advertising strapline on an A.G. Barr delivery truck.

Figure 2.2 A.G. Barr 1957 delivery truck



Notes: Source: AG Barr archives - post the end of World War 2, rationing of sugar for most soft drinks brands continued into the mid 1950's and hence it was considered important to let drinkers know when a brand returned to full sugar.

The history of artificial sweeteners can also be traced back to the late 19th century with the 1897 discovery of saccharin by Constantin Fahlberg, (Basson AR, 2021). Saccharin contained only trace levels of calories yet delivered a sweetness some 300 x more intense than natural sugars. Yet its use as an ingredient, and those of the sweeteners that followed, was typically limited to times of national shortage of sugar, such as the two World Wars and the rationing that followed[36]. Consumers regarded the calorie intake from sugar as a key product benefit and early sweeteners were generally regarded as adding a bitter aftertaste to the drink.

It was in the 1960's through to the early 1980's[37] when the established soft drink brands started to introduce 'diet' versions of their best-selling brands and flavours. These drinks were specifically marketed on their combination of a very low-calorie content (one calorie in the case of diet Coke in Figure 2.3) and a more natural and acceptable sweet taste delivered through the development and use of new artificial sweeteners such as Aspartame and Acesulfame Potassium.

[36] Whilst WW2 ended in 1945 - sugar rationing in the UK continued through until September 1953 hence the use of artificial sweeteners was common place in soft drinks for a near 15year period in the middle of the 20th century.
[37] Diet Dr Pepper launched in 1963 followed by Diet Pepsi in 1964, Diet IRN-BRU in 1979 and Diet Coke in 1982.

Figure 2.3 Diet Coke 1982 initial launch advert "just for the taste of it"

Notes: Source: Coca Cola archives (public domain) – this is the original launch poster advert for diet Coke – complete with the strapline 'Just for the taste of it. Only one calorie'.

Highly pertinent to this study is the **binary nature** of the consumer choice at the turn of the 21st century. The consumer either purchased a full sugar version, often erroneously referred to as 'full-fat', or the diet version of any given parent brand. Very few brands were blending sugar with sweeteners to balance taste and calorie content. In short, when purchasing a 330ml can the drinker faced a choice of either no calories[38] or circa 140 calories per can.

At the end of the first decade of the 21st century, consumers seemed happy with this binary choice. Mid-calorie products (drinks that contained half the sugar blended with sweeteners) had been launched and marketed to consumers, but had quickly failed. Coca Cola C2 and Pepsi Edge both launched in 2004 and were clearly positioned as half-way house or mid-sugar options that blended sugar with sweeteners. However, consumer rejection of the concept and the liquids meant these sub-brands were withdrawn from market shortly after launch. Similarly, in 2013 Coca Cola launched a new product concept called Coca Cola Life. This drink blended 70% of the sugar of regular Coke with the natural sweetener Stevia, all presented in a new and distinctive green packaging.

Whilst Coca Cola Life also failed to make any long-lasting impression on the UK consumer, it was in the same year when arguably the seeds for the UK SDIL policy were perhaps sown. Quietly, with no marketing or consumer announcement, Coca Cola Enterprises in the UK cut

[38] From 2010 onwards, a number of soft drink brands moved from the use of the word "Diet" to "Zero" to differentiate their no added sugar versions.

the sugar levels of some of their other largest carbonate brands (Dr Pepper and Fanta) by 30% and replaced the removed sugar with artificial sweeteners to maintain the sweetness level of the drinks. No-one really noticed the change, including the vast majority of the heavy drinkers of these brands and there was no discernible impact on market share (Table 2.1)

Table 2.1 £ Value % Market Share of Carbonates 2011 – 2014 (Source: Nielsen)

	2011	2012	2013	2014
Dr Pepper	2.63%	2.62%	2.62%	2.65%
Fanta	3.78%	3.87%	3.80%	3.88%

Notes: Market share % is a key measure of brand health and there seems to be little evidence of any material change post the 30% reduction in sugar (and replacement with Sweeteners) which occurred in 2013 / 2014 on Fanta and Dr Pepper

2.2 The UK Soft Drinks Industry and the History of Sugar Reduction

By the end of the first decade of the 21st century, UK Soft Drink manufacturers had been encouraging consumers to switch from regular into diet variants of their brands for some time and with some clear success. For example, by the start of 2011, the volume sales ratio in the UK grocery market of diet (no added sugar) to regular (full sugar) aggregated across the 3 largest carbonate brands (Pepsi, Coca Cola and IRN-BRU) had reached a 51.5% to 48.5% split *in favour of diet* (Nielsen EPOS 2011). In some 30 years the diet variants of these brands had gone from nothing to accounting for the majority of sales in the overall master brand.

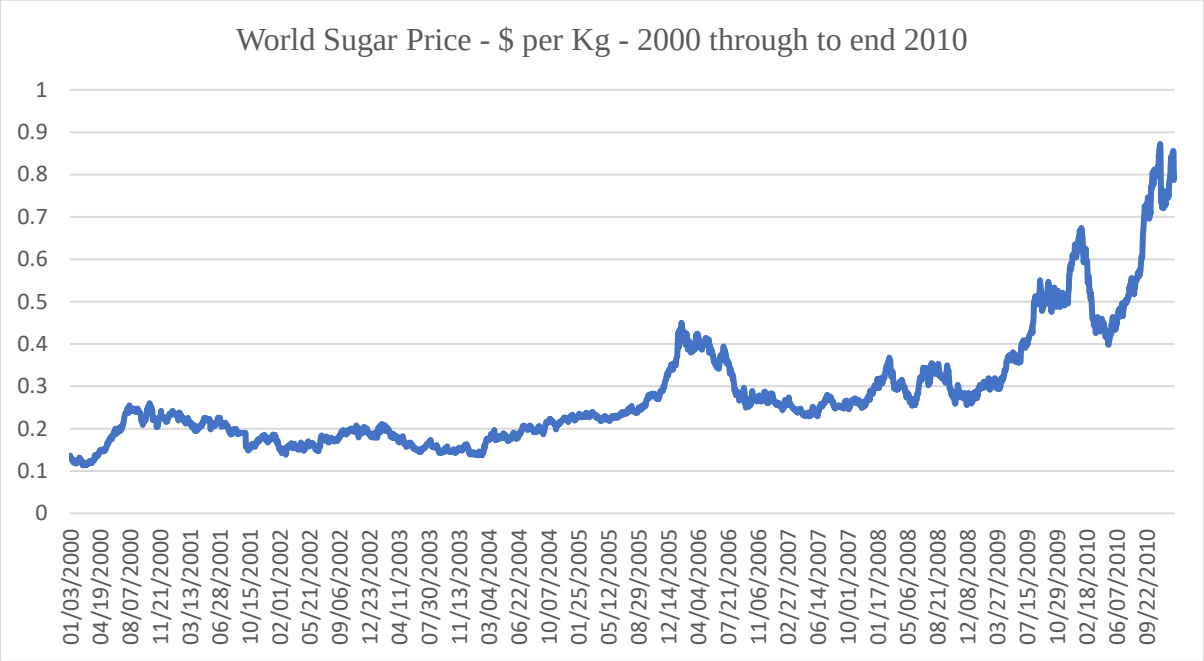
Specific, heavyweight marketing campaigns (Figure 2.4) continued to encourage new drinkers into these no added sugar versions through adverts such as the 'Diet Coke Break', 'Pepsi – Live Life to the Max' and 'Sugar Free IRN-BRU Spot the Difference'.

Figure 2.4 'Diet' variants - advertising campaign examples

Notes: Source: Campaign and Marketing Week (2000 – 2009) examples of diet or no added sugar carbonate adverts at the start of the 21st century.

There were arguably four main motivations for the soft drinks industry to encourage consumers into the no or lower sugar versions of their brands. The first was commercial profit maximisation. Until the launch of the SDIL there had been a long-established wholesale and retail principle that sugared and diet variants of the same brand were sold at the same cost and retail price points. Yet sugar, as a sweetening ingredient, was (and still is) significantly more expensive than artificial sweeteners (AG Barr 2025). Across the first decade of the 21st century soft drinks producers had seen the cost of sugar near quadruple from $0.13 (1999) to a peak of $0.87 (2010) dollars per KG as shown in Figure 2.5 (Macrotrends Commodity Pricing 2024).

Figure 2.5 Global Price of Sugar (Source Macrotrends)

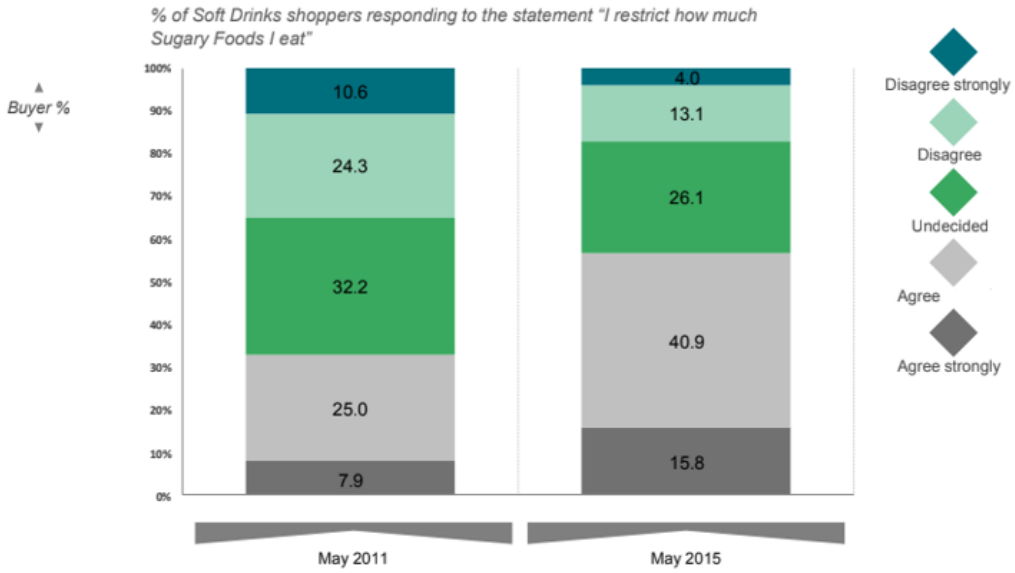


Notes: This increase in sugar costs was keenly felt by the soft drinks industry and provided significant incentive to encourage consumers into diet variants.

Given that in 2010 most 2L regular bottles would have contained some 200 grams of sugar this created a significant profit-based motivation for brand owners to switch their regular drinkers into the no added sugar versions of their products. There was also evidence from Kantar of a potential guilt-free consumption benefit with panel data recording those households that purchased diet drinks on average purchasing 10% more liquid than those households who only purchased regular drinks (AG Barr / Kantar research 2008).

The second motivation was the consumers themselves. Figure 2.6 presents a chart taken from a further attitudinal study commissioned by AG Barr from the Kantar Worldpanel (30,000 UK households) in May 2011 and then repeated in May 2015. The figure clearly highlights changing consumer attitudes towards sugar.

Figure 2.6 Changing consumer attitudes towards sugar (Source: AGB / Kantar)



Notes: Notes: AG Barr proprietary research commissioned through Kantar. Consumer understanding is key to a brand owning business and this research was placed to better understand changing attitudes towards sugar.

The % of consumers who agreed or strongly agreed with the statement "I restrict how much sugary food I eat" increased from 32.9% to 56.7% across this four-year time period.

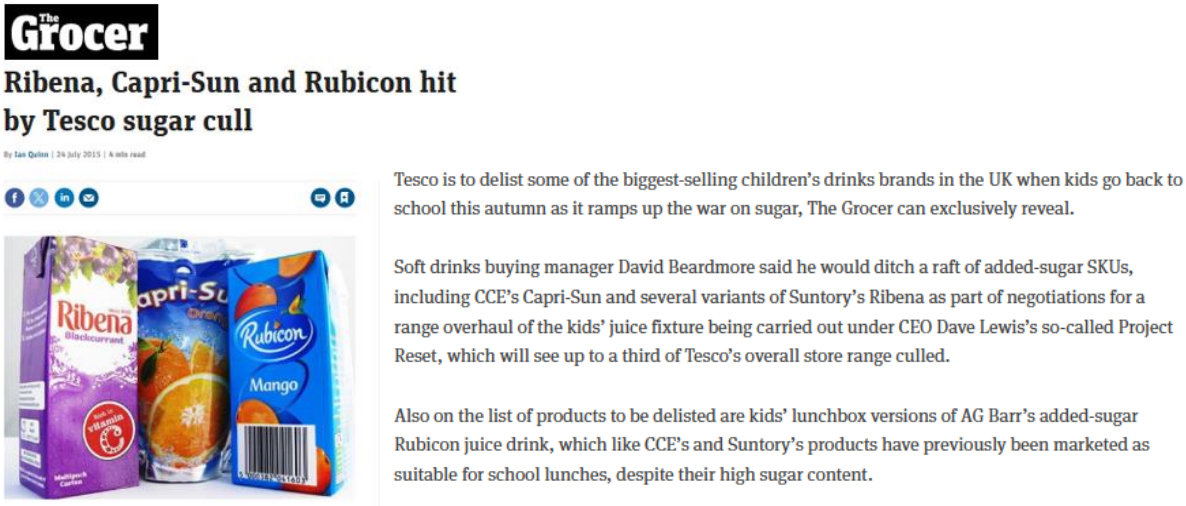
These changes in consumer preferences can logically be associated with a significant and marked increase in media coverage highlighting the link between high sugar consumption, obesity and associated health issues (Elliott-Green, et al., 2016).

The third motivation is perhaps less visible to those not working in the grocery industry as it flows from the private conversations and commercial negotiations between brand owners and their major customers. Figure 1.1 showed the concentration of market share in the leading UK grocery retailers, many of whom look to reflect their shoppers (public) sentiment in the listing decisions they make, e.g. what products they choose to sell from their shelves. A good example of this is Tesco (the largest UK grocery retailer) who across 2012 – 2013 actively encouraged brand owners to deliver sales growth via no added sugar rather than sugared soft drinks.

A simple way that retailers could encourage consumers into no added sugar variants was by placing the diet variants into deeper levels of store distribution within their store estates. For example, in Tesco in 2013, IRN-BRU 500ml Sugar Free was available in circa 1,500 stores whilst IRN-BRU 500ml Regular was sold in less than half of this number of stores despite IRN-BRU Regular having a higher weekly unit rate of sale (Nielsen 2013).

In 2015, retailer led support for sugar reduction manifested itself in a more public level of influence when Tesco announced they were delisting all drinks containing added sugar from their children's 'lunchbox fixture' (Figure 2.7). Grocery brands depend on listings in the major supermarkets and hence it is very logical that this type of direct action, by what at the time would have been most producers' largest single customer, would focus the resources of the producer on the development of no added sugar propositions.

Figure 2.7: Retailer / Tesco influence on sugar reduction (source: The Grocer July 2015)



The Grocer

Ribena, Capri-Sun and Rubicon hit by Tesco sugar cull

By Ian Quinn | 24 July 2015 | 4 min read

Tesco is to delist some of the biggest-selling children's drinks brands in the UK when kids go back to school this autumn as it ramps up the war on sugar, The Grocer can exclusively reveal.

Soft drinks buying manager David Beardmore said he would ditch a raft of added-sugar SKUs, including CCE's Capri-Sun and several variants of Suntory's Ribena as part of negotiations for a range overhaul of the kids' juice fixture being carried out under CEO Dave Lewis's so-called Project Reset, which will see up to a third of Tesco's overall store range culled.

Also on the list of products to be delisted are kids' lunchbox versions of AG Barr's added-sugar Rubicon juice drink, which like CCE's and Suntory's products have previously been marketed as suitable for school lunches, despite their high sugar content.

Notes: The Grocer is the main news journal for the Grocery industry and reported this story in the summer of 2015 in response to a press-release from Tesco.

Whilst sugar sweetened beverages (SSBs) with their sweet taste are pleasurable to drink, when consumed either in excess or over a long period of time without balancing calorific activity, their high sugar – and hence high calorific content has the potential to give rise to obesity and its many associated health issues. Most developed countries including the UK have, and continue to experience, a severe and growing obesity problem. In England in 2019 some 28% of adults were obese with a further 36.2% overweight (Baker, 2021). More concerning is the trend in children, with the 2019 data showing some 21% of 10 – 11 years olds classified as obese and a further 14.1% as overweight. A similar pattern to England could also be seen in other UK nations (Baker, 2021). There is a long list of health issues associated with obesity including type 2 diabetes, coronary heart disease, cancers and strokes (NHS, 2019), as well as the increased risk from pandemics such as Covid-19 ((Popkin, et al., 2020). There is a substantial literature which provides well documented links between the consumption of sugar

sweetened beverages (SSBs) and obesity including a detailed and highly influential report entitled 'Sugar Reduction: the evidence for action' published by Public Health England (2015).

Hence the fourth and final motivation for a voluntary led approach to soft drink sugar reduction was a UK Soft Drinks industry *under significant attack for its contribution to obesity*. This attack came from various stakeholder groups and individual campaigners. Most scientifically noteworthy were the policy statements from the World Health Organisation (WHO), the British Medical Association and the academic pressure group Action on Sugar. In March 2015 the WHO stated that of the recommended daily calorie intake of 2,000 calories no more than 10% and *ideally less than 5%* should come from free sugars. This was a very significant statement, as at the time a typical 'can a day' of 330ml SSB contained circa 140 calories or 7% of the recommended daily calorific intake.

The concerted campaigning from science-led institutions was very effectively supplemented by sugar reduction campaigns led by celebrities, such as the campaigning chef Jamie Oliver. A documentary entitled 'Jamie's Sugar Rush' calling for the introduction of a sugar tax on SSBs was viewed by some 1.4m people and was responsible for a parliamentary petition to introduce a sugar-tax gaining over 100,000 signatures some 48 hours after the airing. Finally, the focus on SSBs and their link to obesity added further strength to a long held campaigning position from UK dentists which called for policy intervention based on the impact of SSBs on dental health and the incidence of tooth decay in both children and adults (Oral Health Foundation 2014).

2.3 Internalities, Externalities and 'Sin Taxes'

The link between the excessive consumption of SSBs and poor health outcomes implies that the drinking of SSBs exhibits externalities and internalities for both society and the individual. In the UK, people can easily access the necessary hydration from free or low-cost tap water. Yet UK consumers spend some £20bn a year on soft drinks, of which the majority is spent on SSBs[39]; with their combination of sweetness, taste and often carbonation, making them far more pleasurable for most consumers to drink than tap water. SSBs are a clear temptation good; they are immediately pleasurable but can involve a subsequent cost to the individual. The strength of the internalities is such that drinkers may suffer from a self-control problem (Schmacker & Smed, 2023). The over consumption challenge associated with SSBs was investigated in the BBC documentary 'Addicted to Pleasure: Sugar', first aired in 2012. This documentary showed how actual consumption could exceed planned consumption (an intentions-behaviour gap) with consumers yielding to the temptation at the point of making the drinking choice. The documentary clearly showed how this choice could be to the detriment of the long-term interests of an 'addicted' drinker.

A further driver of excessive consumption of SSBs may also lie in the lack of consumer awareness or understanding of the high sugar and hence calorie content contained in a regular SSB serving. A common reference point on sugar for many consumers is how much sugar a drinker might add to the offer of a mug or cup of tea, with the question normally phrased as 'do you take 1 or 2 sugars?' (teaspoons). When observing consumer research focus groups[40], you can visibly see how surprised most consumers are when told that most pre SDIL regular SSBs typically contained between 7 and 8 teaspoons of sugars per 330ml serve – 'who in their right mind would ask for 7 or 8 sugars to be added to their cup of tea?'

To try to improve awareness of the sugar content of soft drinks the industry (alongside food manufacturers) voluntarily adopted a standard traffic-light, front of pack, labelling framework in 2014 (Figure 2.8). The high sugar content of a regular can is shown on front of pack both in terms of the number of grams and as a % of RDA, all highlighted by the red traffic light. There is however clear evidence that despite this packaging intervention, consumers' assessment of the sugar content of food and drinks in relation to recommended intakes remains

[39] In the past 12 months (data to end Oct 2025) across the top 100 brands sold in UK grocery, Circana EPOS still records a majority of £ value sales (some 52.2%) in SSBs compared to diet drinks, those with no sugar, or with sugar naturally occurring such as fruit juice.

[40] As part of the reformulation development I personally attended numerous consumer focus groups (sitting behind a one way mirror to both observe and listen) held to better understand consumers relationship with sugar and how it was changing.

imperfect (IGD, 2020) and arguably in the Figure 2.8 example, the red traffic light on a red background doesn't quite stand-out as clearly as the green traffic light on a red background.

Figure 2.8 Traffic light labelling on soft drinks – example Coca-Cola 330ml Can

Notes: This can was purchased in March 2024 and shows the consistent industry lay-out for showing the RAG colour (based on the Nutritional Profile Model) and % of an RDA.

Externalities arise because of the negative impact caused by the consumption of SSBs on people's health and the aggregate cost then placed on society. In 2025 the Department of Health and Social Care (DHSC) estimated the financial cost of obesity on the NHS alone to be some £11.4bn (2025). In 2025 NESTA (the UK's innovation agency for social good) commissioned a report which showed the financial cost of obesity through reduced productivity and absenteeism to be some £30.8bn, whilst the overall societal cost as recorded by the DHSC is some £74.3bn.

The presence of these clear externalities, alongside a lack of consumer understanding, suggests that the consumption of SSBs may be inefficiently high and hence there is a role for public policy in correcting this market failure. Whilst some policy makers would focus on better labelling and the promotion of healthier choices, others would turn to a classical 'sin tax' response. In 2017 the WHO passed a resolution calling for sugar taxes to be implemented across the globe. The basis for this intervention was the simple hypothesis that the addition of an appropriately calculated sin tax would ensure the final retail price, paid by the consumer, fully reflected the full cost of consumption (including the externalities). The associated demand response would then return consumption to a more efficient level. These types of taxes have been broadly implemented for goods such as alcohol and tobacco – and it is interesting that the subsequent WHO 'sugar-tax manual' leads with a quote from Adam Smith which places sugar firmly in the sin tax taxonomy:

"Sugar, rum, and tobacco are commodities which are nowhere necessaries of life, which are become objects of almost universal consumption, and which are therefore extremely proper subjects of taxation." **Adam Smith, An Inquiry into the Nature and Causes of the Wealth of Nations,** (1776)**.**

Perhaps a more contemporary interpretation of sugars inclusion in the 'sin-tax grouping' was to be found in January 2014 on the front page of The Daily Mail tabloid newspaper which led with the headline "SUGAR IS THE NEW TOBACCO" (Figure 2.9).

Figure 2.9 UK tabloid newspaper sugar tax headlines

Notes: Source and copyright permission granted by The Daily Mail January 2014 and October 2015 – headlines are illustrative of the pressure for some form of policy intervention on sugar. In 2014 the Daily Mail had a circulation of some 1.5m readers.

In October 2015 a further "GREAT SUGAR TAX COVER UP" front page headline was printed reflecting the increasing broader media campaign for policy intervention (Figure 2.9). Yet in 2014 and 2015 and even on a global basis, the policy of taxing sugar content in soft drinks was still very much in its infancy with little empirical evidence of its effectiveness.

2.4 Existing Global Sugar Taxes

By the end of 2023, across the world, there were some 132 ‘soft drink - sugar tax’ policy interventions in place covering 120 countries (Obesity Evidence Hub 2024). Based on the last revision date of each specific tax, only 14 of these policies were effective prior to 2010 which underscores the clear momentum behind regulatory intervention and the recent introduction of taxes around the world (Griffith, et al., 2019).

It could be argued that regulators in one country watch very closely what happens in another with the World Health Organisation (WHO) both making the case for intervention and acting as a highly effective resource hub for countries considering the policy (WHO – ‘Manual on Sugar-Sweetened Beverage (SSB) Taxation Policies’ 2022).

There are two main routes by which a sugar tax can reduce the externalities or harmful effects of consumption. The first route is a mechanism which sees the retail price paid by the shopper increase, and hence triggers a simple demand side effect which is reduced purchasing and consumption. The second route, which is perhaps more complex and nuanced is a policy which encourages the producer or retailer to change the shopper or consumer proposition. These supply side responses include reformulating the actual liquid to reduce the amount of sugar consumed per ml, reducing or limiting the portion size per serve or the introduction into the market of new product development focussed on low or no added sugar ranges. Some interventions arguably have a foot in both the demand and supply side, for example decreasing the advertising effectiveness of SSBs through a ban on the scheduling of SSB adverts during high reach family TV programmes, but not applying the same restrictions to diet variants, may encourage brand owners to divert advertising investment away from SSBs and into no added sugar variants. Whether it is the demand side, the supply side or a combination of both, it is the specific structure of the tax which will drive the response. However, a researcher (eager for insight post the shock 2016 SDIL announcement) would quickly find that sugar taxes were not typically ‘one size fits all’ policies and the initial taxes were far from uniform in their design, with different constructs in different regions and countries.

The first obvious segmentation point or delineation is whether the SSB tax is implemented on a national basis, such as Chile and Mexico who both implemented taxes in 2014; a regional basis, such as Catalonia who implemented a policy in 2017 some 4 years ahead of the rest of Spain; or even on a city-wide basis, such as Oakland, Philadelphia, Albany and Boulder all U.S. ‘cities’ who introduced soft drink sugar taxes in 2017.

The scale of the region covered by the tax is crucial to both the consumer demand and perhaps more importantly the supply side response to the policy. A sugar tax implemented at a local level in a small market can easily be avoided by consumers purchasing in a neighbouring region (Cawley, et al., 2019a) , (Cawley, et al., 2019b).

Sugar and carbonation are natural preservatives, and alongside other added preservatives can extend the shelf life of liquid in a typical 330ml can to some 12 – 24 months[41]. This provides the consumer with an opportunity to bulk buy outside the taxed region at lower (non-taxed) prices. More significantly the limitation of a local or even regional sugar tax provides a disincentive for any supply side reformulation. Significant diseconomies of scale, in purchasing, production and stock management combined with the potential negative consumer reaction to different formulations in a small geographical area effectively rule out a regional reformulation response. The efficiency in the soft drink supply chain (a modern can line will fill and pack some 32 cans *per second*) coupled with minimum order quantities (MOQ's) from suppliers (for example a can supplier would typically have a minimum production run of 250,000 identical cans) mean that even at a regional level, brand owners would be reluctant to produce specific products for the taxed market. Catalonia could be considered a good example of this regional challenge where the tiered construct of the tax is similar to the UK (Fichera, et al., 2021). However, whilst the region has a population of some 8 million people it still represents only a 1/6th of the overall Spanish market and hence the main producers would face significant diseconomies of scale associated with any regional response.

The second delineating factor is the nature or construct of the tax itself as shown in Figure 2.10.

Figure 2.10 Main types of Sugar Tax structures in use across the world

Sugar Tax Type	Description
1. Ad Valorem	A % tax added based on the retail price of the product. This can be applied to all soft drinks, or restricted to SSBs.
2. Ad Valorem - Tiered	The option to vary the % of the ad valorem rate according to specific level of sugar content in the drink
3. Excise Volume	A tax on the liquid volume which can be applied to all soft drinks (such as the initial French 7 cents per litre) or on the use of sugar as an ingredient in SSBs calculated on a simple cost per weight used basis, for example the 1.5 cents per ounce recommendation found in Allcott et al., (2019)
4. Excise Volume - Tiered	A volume tax as above, but with different costs per weight or litre based on the sugar content of the final liquid
5. Import Duty	In some geographies where there is no or limited domestic soft drink production it is possible to create a sugar tax by applying different import tariffs based on the sugar content of the drinks being imported.

Notes: Source is the World Bank Group Global SSB Tax Database (2023) of taxes on SSBs around the world.

[41] AGB extended shelf life testing and observations of in market best before dates on leading brands.

At this early stage it is important from a UK perspective to clearly differentiate between VAT as an Ad Valorem *sales tax* and the SDIL as a *soft drinks industry sugar tax*.

The sales-revenue based Value Added Tax (VAT) has been applied to what are considered non-essential goods and services, and specifically to the majority of soft drinks (in contrast to most food items) in the UK for over 50 years. Initially at a rate of 10% and currently at 20%, VAT on soft drinks raises circa £4bn of tax revenue for the UK Government each year (HMRC 2024) *but it should not be regarded as a sugar tax.*

With the exception of milk-based liquids, VAT in the UK applies to all soft drinks regardless of the sugar content[42]. Since introduction in 1973 through to 2018, VAT has arguably had no impact on consumer preference for sugared vs non-sugared soft drinks because throughout this period, regular and diet versions of the same parent brand have typically been sold at retail price parity or 'line pricing' (Nielsen / Circana EPOS). However, as we will later explore across both this and the following chapter, VAT does have a key role to play in the detailed workings of the UK SDIL by *amplifying the impact of the levy* with producers, retailers and consumers.

In some markets, such as Paraguay it is hard to distinguish between a soft drinks tax and a general ad valorem tax. The current ex-factory rate of 5% (set in 2015) is applied to both sugar and non-added sugar beverages including fruit juice. An example of the evolution of an ad valorem tax into a 'proper' sugar tax is Peru. In 2017 all soft drinks categories considered as 'luxury goods' were subject to the UK equivalent of VAT at 17%. In 2018 this increased to 25% on all SSBs which contained more than 6 grams of sugar per 100ml. In 2019 the rate on drinks containing less than 0.5 grams of sugar per 100ml (diet drinks) dropped from 17% to 12%, effectively creating a three-band structure at 12%, 17% and 25%. In 2021 the threshold for the higher tier was dropped from 6 grams to 5 grams.

The main alternative to a cost price or retail price 'sales tax' is for the tax to be calculated on a per litre or volumetric basis. An early example of this is the 2012 'soda tax' in France, which was initially applied at 7 cents per litre regardless of whether the drink contained added sugar or was artificially sweetened. In contrast, Mexico implemented a 1 peso per litre soft drinks tax in 2014, but the tax only applied to SSBs.

[42] There are many vagaries within UK VAT classification with fruit juice and plain water in the 'non-essential' category whilst cold coffee and flavoured milkshakes (both drinks that are typically very high in sugar and calories) being considered 'essential' and hence exempt from VAT.

Finally, a number of smaller countries or islands with no or limited local production are able to implement a sugar tax through import duties or custom tariffs that are applied to higher sugar content drinks. An example is the island of Bermuda where a regular Coca Cola faces a 75% import duty whilst none is applied to the Diet Coke equivalent.

As these policies started to be implemented around the world they understandably attracted academic attention providing the opportunity for both highly relevant and impactful research. In 2016 the global clamour for the introduction of SSB taxes was both tenacious and loud, but would early evidence of their effectiveness provide the impetus for further regulatory momentum?

Griffith et al. (2019) provides a comprehensive review of the early sugar tax research, which typically sets-out to answer the two-part question: what impact has the introduction of the SSB tax had on the price the consumer pays for their drinks (the pass-through rate); and what impact has any change in pricing had on consumer consumption? The natural extension of the research is to translate any change in consumption or consumer preferences into an aggregated or per capita calorific change. The simplest way to try to answer this question is via a before and after comparison: did the introduction of the soft drinks or sugar tax result in a change in consumption trends and patterns?

The challenge with the soft drinks market is that it is highly dynamic and is naturally full of confounding factors such as new product development (for example the Prime sports drink phenomenon which disrupted the market in the UK for 12 months), high levels of demand-influencing advertising spend and sponsorship (Coca Cola's annual report for 2023 details investment of some $5bn in building equity and influencing demand), significant retailer influence on what products are placed before shoppers and of course the natural demand variation caused by year on year weather patterns. To account for these factors some studies have compared the taxed country or region with a suitable control group where there has been no policy intervention. It is arguably much easier to find this control group where the tax is local, yet the research is more likely to be compromised by the presence of spill-over effects. For national based policy research, the soft drinks market or equivalent categories in other countries can be used to form suitable control groups, however the continued presence of confounding factors may require researchers to find suitable groups of other products outside of soft drinks to use as a comparison. All of this ideally requires access to high quality data such as market level EPOS, customer loyalty card data or household panel data.

In March 2016, at the time of announcement of the UK SDIL the 'sugar-tax' literature was naturally limited both by the few jurisdictions where policy had been implemented and the timeframe required for robust analysis to be completed and published. Hence the insight available was limited to a handful of studies.

One of the earliest soft drink taxes was implemented in France in 2012 where a levy of 7.16 cents per litre was applied to all soft drinks, *regardless* of sugar content[43]. Beradi et al. (2016) uses non-volume weighted store-level price data and finds there to be a full pass-through of the tax and almost full pass-through for fruit-based drinks with no evidence of over-shifting of the tax. In contrast a later study that uses an exact price index (EPI) approach to household panel data finds the pass-through to be only 40% (Etile, et al., 2018). Finally, Capcci et al. (2019) studies a different set of panel data covering two different French regions and finds full pass-through for the sodas and partial pass-through for the fruit juice but no evidence that the tax led to a reduction in volumes purchased. This last point is perhaps consistent with a hypothesis that most soft drinks represent a relatively inexpensive 'sharing treat' for households.

In recent years a high degree of 'overall soft drink inelasticity' can arguably be seen in the UK market where, between the calendar years 2020 and 2024, the average price per litre in Grocery stores increased from £1.15 to £1.55 or just over 35% (Circana 2020-2024) which was significantly ahead of the 25% increase in average wages (ONS 2020-2024) *yet, soft drink purchase volume fell by only 1% over the equivalent timeframe.*

It was only in 2018 that the French soft drinks tax was modified to reflect sugar content, whereas Mexico launched in 2014 with what can be regarded as a true sugar tax. One peso per litre, which translated to circa a 10% retail price increase on the leading brands, was *only* placed on drinks containing added sugar, with a single added gram sufficient to trigger the tax. Both Colchero et al. (2015) and Grogger (2017) measure the pass-through of the tax using a price database, with the earlier paper finding over-shifting only on the carbonated variants of SSBs whilst the later paper found a 14% increase on taxed SSBs (some 40% ahead of a straight pass-through) and no increase on non-taxed drinks. In terms of the impact on consumption, Colchero et al. (2015) found purchases of the taxed drinks declined by 6% and non-taxed drinks increased by 4%. However, unpacking this headline shows a marked difference between the performance of the carbonated SSB brands (no volume impact) and the impact on the still fruit

[43] The original legislation as passed in 2011 only applied the tax to SSBs, but this was later amended to reflect both SSBs and non-SSBs. The title of the Beradi paper references a 'soda tax' evaluation, this is arguably misleading as the tax was applied to all drinks with the exception of fruit juice and plain water.

drink SSB brands (accounting for all the taxed decline). Further analysis of the Mexico policy by Aguilar et al. (2021) using an event-study design and household panel data estimates a calorie fall of some 2.7%, a level which was very similar to the 3.8% volume reduction on taxed products found by Arteaga et al. (2021) using a time series approach applied to 'sales out' data from manufacturers. Whilst sales data from the actual producers to their customers is one step removed from the consumer, in the long run there will be consistency between the two sources. The two main confounding 'watch-outs' of using this type of data are retailer stock builds prior to the tax implementation date (forward buying) and imports of global brands from other countries who may not be subject to the same tax policy (lost from the analysis).

Chile also introduced a type of sugar tax in 2014, but took a very different approach to Mexico. Building on an existing 13% ad valorem tax (not dissimilar to VAT in the UK), thresholds or tiers were introduced to vary the ad valorem rate based on the level of sugar. Drinks containing over 6.25 grams of sugar per 100ml saw the ad valorem rate increase to 18% whilst those below 6.25 grams saw the ad valorem rate fall to 10%. Both Caro et al. (2018) and Nakamura et al. (2018) use panel data to evaluate the impact of the introduction of these different ad valorem rates based on sugar content. Caro et al. (2018) found a 2% increase in the price of > 6.25gram SSBs with a fall in both volume and calorie intake by 3.4% and 4% respectively. Nakamura et al. (2018) found more substantial reductions in the volume of high-sugar SSBs but considerable variability based on the empirical model chosen and the level of significance.

Whilst the tax changes in Chile were arguably modest (an 8% point variation between SSBs and non-SSBs), they represented a clear policy evolution which could be traced from France to Mexico to the introduction of different thresholds in Chile. This evolution continued with the sugar tax regulations introduced in Portugal in February 2017, which saw a combination of sugar thresholds *and a volume-based approach*. High sugar drinks (as defined by sugar levels ≥ 8 grams per 100ml) were subject to a tax rate of 16 cents per litre, whilst drinks below the threshold were subject to an 8 cents tax per 100ml (e.g. diet variants were also taxed albeit at half the rate). Goncalves and Dos Santos (2020) use store level price and sales volumes from a single supermarket chain to investigate the impact of the tax. They find the tax was fully passed through to both high sugar and no added sugar drinks and over-shifted for drinks that sit below the 8 grams threshold but still contain some added sugar. This last point may provide the rationale for why there was no observed fall in the sales levels of high sugar drinks yet there was in lower sugar drinks.

Catalonia, the example shared earlier of a regional implementation, also went live with a threshold structured, volume based, sugar tax ahead of the UK April 2018 implementation date. However, unlike Portugal, the structure of the tax thresholds offered the opportunity for the tax to be avoided entirely if the SSB was reformulated to below 5 grams per 100ml of sugar. Whilst the thresholds in Catalonia were the same as those proposed at the time for the UK (0 cents at 0-5 grams, then 8 cents at 5-8 grams and 12 cents at 8 grams+) the quantum of the actual tax rates was much lower (accounting for the exchange rate just less than 50%) than those proposed in the UK.

Castello and Casasnovas (2020) use sales data from a single supermarket chain (representing circa 10% of grocery sales in the Catalonian region) to record a full pass-through of the tax, a price elasticity of -0.509 and a 7.7% reduction in SSB purchases with some substitution into the light / diet equivalent variants. However, a limitation with this paper is the 90% of purchases that cannot be observed. Fichera et al. (2021) employ a stronger data set (loyalty card data) and a DiD methodology that compares the purchases of shoppers in the Catalonia region with the soft drink purchases of loyalty card holding shoppers in other Spanish regions. The study finds a 2.2% reduction in the purchases of SSBs post the introduction of the policy, however the initial Catalonian policy intervention arguably contained two main limitations. The first was the relatively short period between the policy being passed by the regional parliament on the 28th March 2017 and the policy being implemented on the 1st May 2017, a time period which effectively ruled out any immediate supply side reformulation response. This response would also be dependent on the brand owner being prepared to reformulate based on only a segment of their market, some 8m people or 1/6th of the national population. The second is the risk of cross border purchases outside of the Catalonian region into both France and other parts of Spain both undermining the policy and creating spill-over effects in any analysis.

The UK intentionally chose a two-year gap between announcement and implementation to encourage reformulation but also benefited from the SDIL policy being entirely consistent across the devolved nations and with the exception of Ireland, who implemented the same policy 3 weeks later, a lack of hard borders with any other countries.

The problem of cross border shipments arguably led to the unusual situation in Denmark in 2014. Whilst many countries were considering regulatory policy to curb consumption of SSBs Denmark took the pragmatic decision to remove a sugar tax (Schmacker & Smed, 2023).

Whilst a soft drinks excise tax had been in place in Denmark since the 1930's it evolved into a true sugar tax when in January 2012 the excise rate was substantially increased (by 50%) for drinks containing more than 0.5 grams of sugar per 100ml relative to those with very low or no added sugar. The tax rate for SSBs was then halved in July 2013 before being fully removed in January 2014. Schmacker & Smed, (2023) use household panel data to analyse both the pass-through and elasticities associated with each of the tax rate changes and document the key reason for the reduction and then removal of the sugar tax. They evidence the impact the higher pricing had on encouraging cross border trade with an estimated 23 % of Danish soft drink volume being purchased abroad (The Danish Ministry of Taxation, 2014). Whilst 'stocking up in Germany' was logical to the shopper, it negatively impacted both tax revenues and the health-based objectives of the policy.

The Danish experience also provides some insight into the importance of the broader food and drink backdrop and narrative. The removal of the tax on SSBs followed shortly after the repeal of a 'fat tax' based on saturated fat content that had been introduced into Denmark in 2011 (Vallgarda, et al., 2015). Whilst subsequent research showed a reduction in saturated fat consumption, at the time of the repeal in 2012 the tax was perceived to be a tax revenue raising intervention, rather than a public health driven policy. This made the 'fat tax' unpopular with the industry and its consumers and hence politically untenable.

In contrast in October 2015 the Guardian newspaper[44] published the results of a ComRes poll that increased the political pressure on the then UK Prime Minister David Cameron. In response to the question: "To what extent do you support or oppose the introduction of taxes on unhealthy food and drinks to improve child health?" a majority (53%) of the 2,000 respondents were in favour of a policy intervention.

[44] In 2015 the Guardian had an average circulation of 170,000 daily readers, whilst the digital version which also carried the results of this poll alongside the headline "David Cameron Faces Pressure To Back Sugar Tax" received some 127m unique monthly on-line views.

2.5 UK SDIL, a Shock Policy Announcement in the March 2016 Budget

One consistent theme in all of this literature is the focus on the demand side impact of the tax, e.g. was the tax passed through and if so what impact did the retail price increase have on consumer choice and consumption? This is, after all, how sin taxes typically work.

Yet for well over two decades the UK soft drink industry had been successful in reducing the average level of sugar per 100ml not through pricing but through a broader range of diet variants, consumers switching into bottled water and some limited liquid reformulation. The question was not whether a sugar tax could halt the growth in soft drink induced consumption of sugar but whether a policy intervention could act as a catalyst *to accelerate* the pace of reduction?

Despite significant lobbying from health bodies, the wider media and 'celebrities' that continued apace throughout 2015, the Conservative government rejected calls for policy intervention (UK Government formal response to Oct 2015 petition). Instead the Government continued to 'encourage' the soft drink industry through public voluntary pledges to continue the evidenced trend of long-term sugar reduction. The British Soft Drink Association (BSDA) responsibility report from 2015 details both an aggregated 7.5% reduction in sugar usage by the industry across the previous 2 years and many of the individual company pledges. The BSDA annual report of the same year, 'Changing Tastes' provides a very clear insight into the industry response to external pressure and changing consumer preferences (Figure 2.11).

Figure 2.11 Perspectives on sugar reduction from the Industry (Source: BSDA 2015)

Changing tastes

The number of consumers switching to low, no and mid calorie drinks in 2014 speaks volumes for industry's efforts to meet changing consumer demands. It means almost half of all carbonates sold in the UK are low or no calorie. Added to that sales of bottled water continued to flourish, up 9.3%, and nearly three quarters of all dilutables sold are low or no calorie. This represents a significant shift.

Driven by a determination to respond to consumer needs and to step up to public health challenges, soft drinks companies have pushed sales of drinks containing fewer calories to unprecedented levels.

Through reformulation, new product development, smaller pack sizes and increased advertising spend of nearly 50% last year alone, soft drinks manufacturers have used a variety of initiatives to achieve their calorie reduction goals whilst still meeting consumer expectations.

But despite the success of some categories overall soft drinks consumption was down slightly by 0.5%. That partly reflects the fall in sales of fruit juice (down 9.5%) - an unfortunate by-product of the misguided campaign on sugar – which sadly means some consumers have reduced the role of fruit juice in their 5 a day. We as an industry will be stepping up our work to address this issue in 2015.

Consumer needs are clearly changing and as an industry we are responding. By providing an ever wider range of products the soft drinks industry plays a positive role in encouraging and helping consumers make the right choice for their lifestyle.

BSDA Director General Gavin Partington

Hence on the 10th March 2016 when the then Chancellor announced the introduction of the UK SDIL *it took the industry completely by surprise*. This surprise related not only to the announcement of the policy but also the detail of the SDIL policy itself.

2.6 The UK SDIL, a Tiered Tax Approach

When the UK Government announced the UK SDIL policy intervention, the implementation date was clearly communicated as April 2018. This extended timeframe supported a consultation process with both stakeholders and the UK soft drinks industry itself, that would run across the balance of 2016 and lead to final legislation ready for presentation before Parliament in early 2017. More significantly, and key to the structure of the SDIL, the near 25 months between policy announcement (March 2016) and policy implementation (April 2018) provided the time required for a supply side response from brand owners, and specifically the time required to reformulate products in response to the tiered nature of the tax.

The UK SDIL applied to any soft drinks where sugar was added as an ingredient with the specific level of the added sugar determining the pence per litre levy rate:

Below 5 grams of sugar per 100ml = no levy

≥ 5 grams to < 8 grams per 100ml = 18p per litre of finished product

≥ 8 grams per 100ml = 24p per litre of finished product

The key exemption within the policy was for drinks containing over 75% milk on the basis of the nutritional value of the milk. Fruit and vegetable juice whilst high in sugar content sat outside of the policy as the sugar content was naturally occurring and not added during the production process. Finally, Squash, a significant category in the UK, was based on the sugar content in the diluted 'as drunk' final liquid rather than the concentrated format.

With the exception of Fanta, Sprite and Dr Pepper (which as described earlier had reformulated to 7 grams in 2013 / 2014 and in doing so arguably provided some of the inspiration for the tiered policy) most soft drink brands sat in either the ≥ 8 grams tier or the no added sugar tier.

2.7 Cost Impact of the SDIL - Producer and Retailers Perspective

All producers were able to quickly calculate the proposed cost impact of the SDIL on their business on a 'do nothing basis'. Dependent on the level of ≥ 5 or ≥ 8 grams per 100ml added sugar volumes in their product portfolio each producer faced a specific quantifiable levy cost and risk to their business from April 2018 onwards.

At AG Barr, which in 2016 had one of the higher ratios of sugar added products in the brands they sold, the calculation was 'stark'. With some 315m + litres of finished liquid in the highest threshold band the levy cost was just over £75m. In the previous financial year AG Barr had reported total pre-tax profits of £41m (2015 / 2016 AG Barr Annual Report). The simple maths showed that a 'change nothing' response was not going to be a viable option for the business. All portfolio soft drink producers faced SDIL challenges, *it was just the extent that varied.*

Most soft drink producers have a methodology for calculating the 'cost of goods' or COGs of any given product line they sell, which supports the calculation of a simple gross profit % based on the invoice selling price to their customers. Included in the COGs makeup are raw materials, variable costs such as labour and energy, fixed costs such as factory sites and production assets. A simple and hypothetical example of a COGs calculation is shown for a 2L bottle of 'Fizzy Pop' in Figure 2.12.

Figure 2.12 Hypothetical example of the COGs for a 2L Regular Bottle

2L Regular Bottle Example	
Bottle preform and label	12p
Liquid costs	15p
Fixed Production costs	6p
Variable production costs	10p
Total COGS	**43p per bottle**
Sell price to Retailer	**65p per bottle**
Cash Profit (% margin) to producer	22p per bottle (34%)
Sell price to Shopper	100p per bottle
VAT	16.6p per bottle
Cash Profit (% margin) to Retailer	18.3p per bottle (22%)

In March 2016 some 100 grams of sugar (the approximate amount of sugar in a litre of regular soft drink) had a raw material cost of circa 5p (based on EU commodity cost of sugar). Hence in a 2L regular bottle the sugar cost was circa 10p per bottle produced (some 2/3rds of the total liquid costs in the example above). The structure of the SDIL effectively proposed to reset the sugar cost as a raw ingredient in this bottle.

Do nothing, and in April 2018 the cost of the same level of sugar in the 2L example would automatically increase for the producer from 10p to 58p. Reformulate to say 7 grams per 100ml (the mid-band) and the cost would increase from 10p to 43p. Drop to just below the 5 grams threshold and the cost of the sugar used would fall from 10p to 5p per bottle as a natural consequence of halving the amount of sugar used in the production. In the first scenario, a 48p per bottle increase is *greater* than the pre SDIL 43p of total COGs for the bottle.

Post the announcement, certain sections of the tabloid media (Figure 2.13) initially tried to create another 'pasty tax'[45] response to put pressure on the Government to reconsider the SDIL, but this campaign quickly lost momentum.

Figure 2.13 Daily Record (IRN-CHANCELLOR) and Scottish Sun SDIL coverage

Notes: The Daily Record and The Scottish Sun were the two most recognisable tabloids in Scotland in 2016 with a combined circulation of 400,000 copies or some 20% of households. The SDIL was initially seen as an opportunity to create a campaign akin to the 'pasty tax', but the momentum was quickly lost.

The other notable aspect in the media coverage was a translation of the SDIL into what it would mean for readers. This is shown in Figure 2.14, although the calculations are arguably incorrect as they don't include the pass-through impact of VAT in the final retail price points.

[45] The media successfully campaigned to have a proposal in the 2012 Budget to simplify the tax treatment of hot takeaway food which would have added VAT to outlet baked products such as sausage roles and pasties overturned.

Figure 2.14 The Scottish Sun – what the SDIL means for you and 'your view':

HIGHER RATE 24p PER LITRE	Grams of sugar per 100ml	Size	Price now	New price
Old Jamaican ginger beer	16.0	500ml	£1.15	£1.27
Rockstar Sours Raspberry 500ml	12.7	500ml	£1.39	£1.51
Shloer Light Red Grape 750ml	11.5	750ml	£1.00	£1.18
Tesco Fiery Ginger Beer 2 Litre Bottle	11.3	2 Litre	£0.55	£1.03
Coca-Cola Cherry Coke 1.25 Litre Bottle	11.2	1.25 Litre	£1.29	£1.59
Red Bull Energy Drink 250ml	11.0	250ml	£1.19	£1.25
Pepsi Regular 2 Litre Bottle	10.6	2 Litre	£1.98	£2.46
Coca-Cola	10.6	330ml	£0.68	£0.76
7up	10.6	1.5 Litre	£1.79	£2.15
Irn Bru	10.3	500ml	£1.25	£1.37
Dr Pepper	10.3	6 x 330ml	£3.55	£4.03
Ribena Blackcurrant 1.5 Litre Bottle	9.9	1.5 Litre	£3.75	£4.11
Tesco Cola 2 Litre Bottle	9.7	2 Litre	£0.55	£1.03
Vimto	9.1	2 Litre	£1.70	£2.18
Lucozade Original	8.7	1 Litre	£1.00	£1.24
LOWER RATE 18p PER LITRE				
Fanta Orange 500ml	6.9	500ml	£1.25	£1.34
Sprite Regular 2 Litre Bottle	6.6	2 Litre	£1.85	£2.21
Tesco Ginger Ale 1 Litre Bottle	5.1	1 Litre	£0.45	£0.63
Schweppes Indian Tonic Water	5.1	1 Litre	£1.19	£1.37
NO TAX				
Lilt Regular	4.6	330ml	£0.65	£0.65
Tango Orange	4.3	6 x 330ml	£3.19	£3.19
Tesco Active Raspberry Sports Drink	4.3	4 X 500ml	£1.28	£1.28
Powerade Berry/Tropical Fruit 500ml	4.1	500ml	£1.25	£1.25
Diet Coke - and other sugar-free drinks	0.0	330ml	£0.68	£0.68

Notes: This coverage was printed in The Scottish Sun on the 17th March 2016, the day after the budget announcement. Whilst VAT is excluded, the coverage quickly translated the structure and levy rates into what the policy would cost readers (assuming a straight pass-through) on some specific drinks in each levy band. Re-produced with the permission of The Scottish Sun.

Interestingly, *none of the media coverage mentioned the possibility of brand reformulation to partially or fully avoid the SDIL*, yet with the backdrop of a significant change in potential sugar COGS in April 2018, each producer needed to carefully consider their response.

2.8 The UK SDIL: Five Producer Response Options

Immediately post the budget announcement, producers had clarity over the impact on costs from April 2018 onwards, and the level of sugar reduction required to avoid this cost. Where there was significantly less certainty was the impact on demand if the SDIL was passed onto consumers in pricing and whether competition would choose to reformulate to avoid the SDIL.

In short, the producer had 5 response options. The first and obvious option was to continue to encourage consumers into the no or low sugar variants of their brands. Whilst this was effectively a continuation of the approach the industry had been taking for the previous decade, the economic value of the consumer switch was significantly altered (in the 2L example the benefit increased by a factor of six from 10p to 58p per bottle). The strength of this commercial incentive manifested itself in further increased investment in low and no sugar brands. This can be clearly seen in Figure 2.15 which details the weight and variant direction of advertising spend within the Cola category. Whilst the % of spend on full sugar variants had been declining for some time, in the first year post the announcement the entire Cola category spend (which increased by 8%) was all directed behind the no added sugar variants.

Figure 2.15 Advertising and media spend on Cola variants pre and post announcement

Advertising spend (Nielsen)	£m	% on no added sugar variants
Year to April 2015	£19.1m	76%
Year to April 2016	£20.1m	84%
Year to April 2017	£21.7m	100%

Notes: Source Nielsen Advertising Spend 2014 to 2018. At the time this data recorded paid for media such as TV, Cinema, Radio and Outdoor, but did not include social media or brand sponsorship. It is important to note this was a business decision by the brand owners and not in response to any enforced policy or advertising restrictions.

Producers could also encourage switching via new product development. Continuing the AG Barr example, late 2016 saw the launch of two new variants on their two biggest brands IRN-BRU and Rubicon. IRN-BRU Xtra and Rubicon Spring were both no added sugar variants.[46]

A second option for producers would have been to launch an additional brand variant at 'mid sugar levels' or just below 5 grams per 100ml, hence avoiding the SDIL entirely. For example, Coca Cola could have kept Regular (Red) Coke, Diet Coke and Coke Zero, but added a new variant as per the C2 positioning detailed earlier in this chapter. Based on the previous poor in market performance of the mid-sugar concept and likely negative reaction from retailers concerned about range proliferation and complexity, it is perhaps not surprising that no producers took this option.

The third option for producers was to choose not to reformulate and to hold the cost pricing to customers despite the additional cost of the SDIL. For the majority of producers this option

[46] In 2024 this NPD accounted for some £67m of sales at retail value across the IRN-BRU and Rubicon brands.

was simply economically untenable. In the case of most regular drinks the SDIL cost was higher than the profit generated from the sale of the drinks, and hence such an option would have quickly put the producer out of business. This is also shown in the Figure 2.12, 2L example where a 48p per bottle COGS *increase* would compare to a pre SDIL gross profit per bottle sold of 22p.

The fourth option was to increase the invoice price of the SDIL impacted products to either fully or partially recover the SDIL cost. As we examined in Chapter 1, one of the misconceptions is that brand owners set the retail price paid by shoppers. Instead brand owners typically sell to a retailer or outlet who then choose what price to sell each product at. Given the SDIL thresholds and rates represent a transparent and easily calculable cost, it would not be unreasonable for brand owners to present their customers with a price increase on the back of the policy introduction. If we continue with the 2L example, a simple full pass-through of the SDIL would see the invoice price per bottle increase by 48p from 65p to 113p per bottle.

However, there are some important pricing factors to consider here. The first is the role of UK VAT. Assuming the retailer wants to hold the cash profit per bottle sold (18.3p) as a constant, they will need to price the bottle to reflect the addition of VAT to the SDIL. Specifically, this means the 24p per litre rate becomes 28.8p per litre once VAT is added. Hence the 2L bottle retail price needs to increase from 100p to 158p rather than 148p (a straight pass-through of 2 x 24p per litre) to reflect the additional VAT. The SDIL rates were always going to be an effective 28.8p and 21.6p rather than the 24p and 18p as published in the budget – with both the SDIL *and* additional VAT being paid to the UK Treasury.

The second factor is the impact of a straight pass-through on one of the Key Performance Indicator (KPI) measures of the producer and the retailer. Margin or profit % is a core industry measure, used for individual performance appraisal right through to how city analysts would regard the results of a FTSE plc. A straight pass-through of the SDIL automatically generates a significant % margin fall for both parties as shown in Figure 2.16.

Figure 2.16 SDIL impact on margin % - a core KPI for the industry

2L Regular Bottle Example	**Existing**	**Including top-rate SDIL**
Total COGS	**43p**	**+ 48p per bottle**
Sell price to Retailer	**65p per bottle**	**113p per bottle**
Cash Profit (% margin) to producer	22p per bottle **(34%)**	22p per bottle **(19%)**
Sell price to Shopper	100p per bottle	158p per bottle
VAT	16.6p per bottle	26.3p per bottle
Cash Profit (% margin) to Retailer	18.3p per bottle **(22%)**	18.6p per bottle **(14%)**

Notes: The new margin %'s shown in Bold Red compare to the old margin %'s shown in Bold Black following a simple mathematical calculation where the cash profit of the retailer (except rounding) and the producer are held constant but the SDIL is fully passed through to the shopper.

The straight pass-through of the SDIL, where there is no tax over or under shifting, creates an automatic fall in both producer and retailer % margin or profitability. For the producer this % margin fall is 44% (or 15% points) and for the retailer 36% (or 8% points). It is not unreasonable to expect industry decision makers to have some element of their performance related reward (bonus) linked to delivering margin % growth and not decline. This is a powerful if not wholly transparent or understood factor in any potential producer and retailer SDIL response.

If we return to a straight pass-through scenario, the final consideration in any cost price and subsequent retail price increase based response, is the impact on demand from the increase in retail price point. In the 2L example, a straight pass-through requires a 58% increase in the shelf edge label price of the product (from £1 to £1.58). Whilst producers will have some understanding of price point elasticities on their brands, this extreme level of increase represents an unprecedented pricing discontinuity and resetting of reference price points.

If the % margin pressure is significant enough, then producers and retailers may pass-through the SDIL on a % margin maintenance basis, in effect adding additional cost to both the invoice price (producer choice) and retail price (retailer choice) respectively. This can be shown via the 2L example, where to hold % margins at each stage of the value chain, the producer would need to charge 137.6p a bottle (more than double the current cost price) and the retailer would need to sell the bottle for 212p, (again more than double the previous £1 price point). This type of response from industry whilst logical, would seem untenable from a consumer perspective.

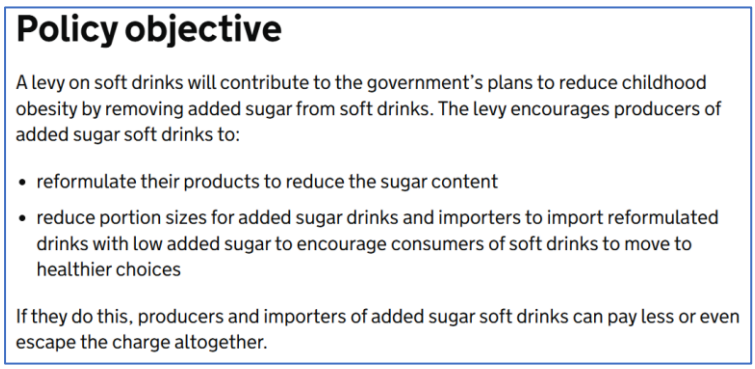
With most carbonate brands offering a regular and a diet variant it would also be reasonable to expect some of the lost sales caused by the increase in price on regular to divert into the diet equivalent. Estimating this level of positive substitution is very challenging: will consumers be more loyal to the brand, the taste or to the use of 100% sugar and the absence of artificial sweeteners? In short, forecasting the impact of the price increase option on demand is fraught with uncertainty and risk. Chapter 3 of this thesis will analyse the detailed pricing impacts, pass-through, mix effects and the demand side impact of the SDIL.

This leaves the fifth and final producer response option – which is to reformulate the liquids in the drinks to either fully or partially avoid the SDIL being applied.

2.9 The UK SDIL, to Reformulate or Not to Reformulate?

When announced in March 2016, the UK SDIL had a unique combination of structural features. The levy was tiered depending on the sugar content but also levied on volumes. This created 'jumps' in tax liability at certain thresholds and the option for producers to completely avoid the levy by reformulating existing liquids to drop the sugar content of the drink below 5 grams per 100ml. It is clear from both the budget announcement and subsequent consultation (Figure 2.17) that the UK Government expected producers to respond to the SDIL tax thresholds and the financial incentive they created by reformulating their products with lower sugar recipes.

Figure 2.17 Policy Objective - HM Government SDIL Policy Paper (Dec 2016)



Policy objective

A levy on soft drinks will contribute to the government's plans to reduce childhood obesity by removing added sugar from soft drinks. The levy encourages producers of added sugar soft drinks to:

- reformulate their products to reduce the sugar content
- reduce portion sizes for added sugar drinks and importers to import reformulated drinks with low added sugar to encourage consumers of soft drinks to move to healthier choices

If they do this, producers and importers of added sugar soft drinks can pay less or even escape the charge altogether.

Notes: This is an extract from the SDIL Policy Objective document which was published post consultation on the 6th December 2016. It is more explicit than either the budget speech, Budget Red Book or SDIL consultation about the role of reformulation.

On the day of the announcement of the SDIL, across the top 100 UK soft drink brands some 51 brands were exempt either because they contained less than 5 grams per 100ml of sugar or

were in an exempt product category. A further 5 brands sat in the mid-tier 5 gram to 8 grams per 100ml band and hence faced an 18p per litre levy. The remaining 44 brands sat above the top threshold with sugar levels greater than 8 grams per 100ml and hence faced a 24p per litre levy. The majority of these brands were in the 10 - 11 grams range and some 8 brands had sugar levels higher than 12 grams per 100ml.

In its simplest form, the reformulation of a soft drink to lower the sugar level from say 10 grams per 100ml to 5 grams per 100ml but to maintain a similar taste or sweetness level, requires the addition of artificial sweeteners to the remaining sugar in the liquid.

The two main challenges in this process are i) the reduction in sugar level can create a different mouthfeel to the drink and ii) artificial sweeteners can impact the taste – and specifically the aftertaste of the liquid.

Research and Development teams, looking for that perfect match, will use additional ingredients or tweaks to the recipe to replicate the mouthfeel and to mask any taste impact from the additional sweeteners.

Once the match has been created it will typically be placed into a Triangular Taste Test (TTT) which presents tasters (the public, and/or professional tasters) with a random '2 original, 1 reformulated' or '2 reformulated, 1 original' combination or liquids and asks them to identify the odd one out. On this basis the product will either pass or fail the TTT for any given statistical confidence level. Clearly sample size is also important in the statistical robustness and hence these TTT's will typically be carried out with hundreds of tasters that can be further segmented based on geo-demographic traits and consumption patterns.

Even if a product passes TTT at the highest confidence levels, most brand owners will require further research to validate the liquid match. For example, a simple TTT may not sufficiently weight the results for heavy and light drinkers, and if 50% of the volume is purchased by 2% of drinkers, it is crucial to understand the 2%'s reaction to the new liquid. TTT liquids are also typically presented in a simple sip test, whereas in the real-world drinkers will often open and reseal a bottle and potentially drink the liquid over an extended period of time. For this reason, in the reformulation of most products a further testing round will see heavy drinkers randomly sent a number of bottles of either the original or new liquid to consume over an extended period of time and to rate the liquids as drunk.

This process takes time, with both quantitative and qualitative feedback loops built into the development process. The liquids also need to be tested at different stages of their shelf life; for example, some sweeteners will degrade faster than sugar and a liquid considered a close match at 4 weeks old may not be a close match by the time it is 3 months old. It is also expensive research, with a decision required on when to stop the process; 'we have achieved a match or we are as close as we are going to get'. Finally, for most soft drinks producers this reformulation challenge applies to many flavours and variants rather than a single liquid in the portfolio. In the case of AG Barr, across the whole portfolio over 100 individual product reformulations were required to avoid the SDIL.

At the end of this technical process the producer will have a clear understanding of whether they have been able to match the existing product and hence the level of consumer acceptability of the reformulated liquid. This researched insight is in often in stark contrast to the potential demand side impact. In simple terms the producer will have access to robust quantitative data detailing the reaction of heavy drinkers to a reformulated liquid, but very little understanding of the same drinker's reaction to a 50%+ retail price increase.

Some final factors in the decision to reformulate or not are:

i) The expected response of competitors. For example, the brand owner needs to weigh up the impact of either being significantly higher priced, 'my competitors reformulated and I chose not too', against the potential benefit of having a differentiated (full sugar) product which may face less direct competition.

ii) The importance of the sales of the brand in the UK relative to sales in the rest of the world. If sales in the UK are de minimis compared to overall sales in Europe, would it make sense to reformulate and present consumers with a different liquid?

iii) The risk of setting a precedent. Similar to the point above a brand owner may value the importance of a consistent product being sold in different regions.

iv) The brand promise itself. For example, Snapple has an iconic strapline, 'made from the best stuff on earth'. On this basis Snapple would only consider reformulation if it was based on using a natural rather than artificial sweetener.

v) Finally, the vertical nature of the market and the concentration of grocery buying power in the hands of a small-number of UK customers will impact a producers SDIL response decision making. If, for example, it was anticipated that retailers may decide not to promote, reduce the number of facings and hence presence of, or

even restrict the store distribution levels of higher threshold products then this would provide an added incentive for producer reformulation. This is further complicated by the fact that the major retailers (who make all these decisions) are also significant soft drinks producers through their own brand propositions and in many cases face exactly the same ‘to reformulate, or not to reformulate’ question themselves.

2.10 EPOS, Nutritional Data, Weather and the SDIL Taxonomy

A detailed overview of the EPOS data used in this study was covered in the introduction. In summary when the unique barcode printed on each SKU is scanned at the checkout a 'beep' is emitted and the system records the unit sale, the volume of liquid in the unit and the price charged within the transaction. These are then aggregated across all EPOS checkouts for any given week. This in turn provides a total weekly value and total weekly volume for the brand from which an average price per litre can be easily calculated. The data used in this study comes from some 45bn individual soft drink units being scanned at checkout or an average of circa 150m units per week across the 288 weeks of data. This is naturally clustered into the 100 brands or some 28,880 data points for each unit of measurement (100 brands x 288 weeks).

This data is arguably the most comprehensive data source that has been used in any evaluation of a sugar tax or levy. It represents the broadest read of the market covering both on-the-go and take-home purchases and is based on actual physical scanned sales rather than the reporting of a representative panel of shoppers. There are clearly some limitations to the data, it does not cover some of the discount customers such as Aldi and Lidl who have historically been reluctant to share their EPOS data with the data companies. It also provides no read for the hospitality market which is more fragmented than retail and does not consistently use the same type of barcode-based EPOS systems to record sales. The overall calorie reduction discussion in chapter 3.14 will show how estimates can be made for both these parts of the market.

The data covers all the categories within soft drinks at an aggregated level and is then broken out for the top 100 soft drinks brands based on £ value sales in 2014. The decision to focus the analysis on the top 100 brands was to retain tractability in merging the necessary nutritional data. A further definition of the word 'brand' is also important as it includes what some might consider sub-brands, for example Total Pepsi is reported as three individual brands in Regular Pepsi, Pepsi Max and Diet Pepsi. This more granular level of brand reporting is necessary to accurately calculate both sugar and hence calorie levels.

The nutritional data (sugar and calories) was collected for the Top 100 brands from weekly physical checks of the actual instore packaging.[47] In the UK it is a requirement for all packaging to carry accurate nutritional information and whilst some brands made no or low-

[47] Fortunately, this data (and the timing of new reformulation introduction) was required by AG Barr for commercial reasons and hence the extensive field sales team completed these checks as part of their weekly store coverage programme.

key announcements relating to reformulation, all were required to change the sugar content in the ingredients panel on the back of the packaging and the front of pack 'traffic-lights'.

This checking process supported a weekly identification of the first point of introduction of any reformulated liquids, identified by any change in the previous weeks recorded calories per 100ml. For example, Regular IRN-BRU recorded calories for w/e 7th January 2018 at 42 per 100ml. The following week the new 20 calories per 100ml reformulated packs started to appear in store and hence this was marked as the start of the pack transition. There followed a natural transition period when retailers would be selling through both the old formulation and the new liquids. Based on insight from the Institute of Grocery Distribution (IGD), the transition was modelled using a linear reduction from 100% to 0% (and vice versa) over a 4-week period.

Finally, weather data covering average weekly rainfall and temperature (mean / min and max) was supplied by Speedwell Weather, a commercial meteorological business that specialises in both forecasting and weather risk management. The weather data was provided for each day of the analysis period and was converted into equivalent weeks to tie in with the specific days contained in each EPOS sales week. The weather data was also provided on a UK wide basis to allow the analysis to de-seasonalise the outcomes by regressing them on controls for temperature and rain-fall. Table 2.2 provides a summary of both the total market and the top 100 brands and hence shows the coverage level within each category of soft drinks:

Table 2.2 Market coverage of the top 100 soft drink brands

	Market		Top 100 Brands			% Market	
	Value	Volume	Value	Volume	N	Value	Volume
Total Soft Drinks	45008.35	53015.54	33050.98	31386.39	100	0.73	0.59
Total Cola	10132.19	9649.76	9956.64	9122.10	7	0.98	0.95
Total OFC	4606.37	4430.20	3738.21	3300.96	25	0.81	0.75
Total Lemonade	884.25	1898.25	376.90	623.72	4	0.43	0.33
Total Sports and Energy	7094.24	3440.53	6329.20	2878.43	15	0.89	0.84
Total Mixers	1172.49	1214.65	664.98	261.40	7	0.57	0.22
Total Carbs	23889.54	20633.39	21065.93	16186.62	58	0.88	0.78
Total Fruit Drinks	5006.72	2902.61	1955.13	1133.45	11	0.39	0.39
Total Fruit Juice	4985.46	3646.56	3399.90	1426.50	8	0.68	0.39
Total Dairy	2018.49	847.87	1013.34	377.35	6	0.50	0.45
Total Water	6431.51	11827.13	4086.43	5873.40	14	0.64	0.50
Total Squash	2676.63	13157.97	1530.25	6389.08	5	0.57	0.49
Total Still	21118.81	32382.15	11985.05	15199.77	42	0.57	0.47

Notes: This table shows consumer spend (in millions of £) and sales volumes (in millions of litres, as consumed, accounting for the dilution of squash) by soft drinks segment for the full observation period from July 27th 2014 to January 26th 2020. It does so separately for the full market covered by our EPOS data as well as for the 100 most popular brands (by £-sales in 2019) that are used for our main analysis. The final two columns show the percentage of consumer spend and volume that is accounted for by these 100 brands.

Table 2.2 also shows that the Top 100 brands accounting for some 73% of total £ retail sales and 59% of total market volume across the 288 week period used in the analysis.

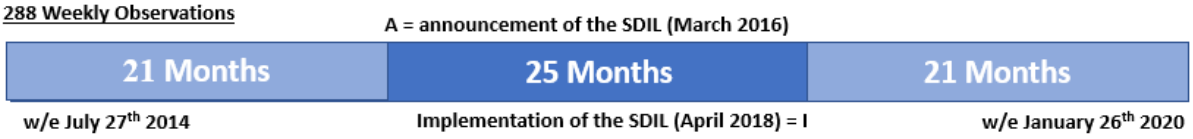
One of the features presented by Soft Drink EPOS data is the sheer number of SKU's available for purchase, with typically over 10,000 unique barcodes being scanned in any given year (Circana EPOS). This level of granularity raises a key clustering question. Specifically, what is the right level of clustering within the highly granular EPOS data to both avoid the risk of auto-correlation and to provide appropriate clustered standard errors within the analysis? (Moulton 1990).

Bertrand et al. (2004) highlighted the importance of this crucial decision and identified the principle of state level clustering for state level DiD policy evaluation. The natural extension of this best practice, when applied to an analysis of the SDIL which utilises sku level EPOS data, is to cluster the data at an appropriate brand level (essentially aggregating each of the individual SKU's within the brand).

This brand cluster approach naturally reflects the level of the treatment assignment from the SDIL. If you think of a brand such as red Coca-Cola, whilst it is offered in different pack formats and now also flavours, the sugar level in the liquid is consistent at 10.6 grams of sugar per 100ml. It is this specific feature which makes it a leviable product and why the brand level (as defined in 2.10) has been chosen for the purposes of this analysis. Furthermore, the decision to focus on the Top 100 brands provides a robust number of clusters to work with.

This timeframe is split into 3 distinct clear periods shown in Figure 2.18.

Figure 2.18 Overview of the 3 data time periods



The decision to end the analysis period at the end of Jan 2020 was based on a combination of the pre and post SDIL time symmetry being achieved and an avoidance of any market distortion caused by the Covid19 pandemic from Feb 2020 onwards.

Table 2.2 also provides a basic taxonomy based on category or segment. With the exception of fruit juice and dairy based drinks each category contains brands that sit both below or within

the SDIL thresholds. Hence to support the analysis (plotting of data and visualisation of key patterns) without the sharing of regression results at a specific brand level (which would be inconsistent with the agreed data usage) a further taxonomy specific to the SDIL was created.

Hence throughout the analysis brands are grouped into one of four SDIL categories:

1. Levied brands, which are high sugar and thus subject to the 24ppl levy. The only brands within this category are either colas or energy drinks, and for some of the analysis they are disaggregated as such.

2. Reformulated brands, that changed their recipes and as a result either partly but usually entirely avoided the levy by the time it was implemented. Note that the inclusion of brands in the reformulated category is based on whether the brand reformulated by the time the levy was implemented, so the composition of categories is fixed throughout the analysis.

3. Diet/no added sugar/sugar free brands, which are artificially sweetened so contain no sugar and virtually no calories. All of these brands have variants either in the reformulated category, or in the full sugar category.

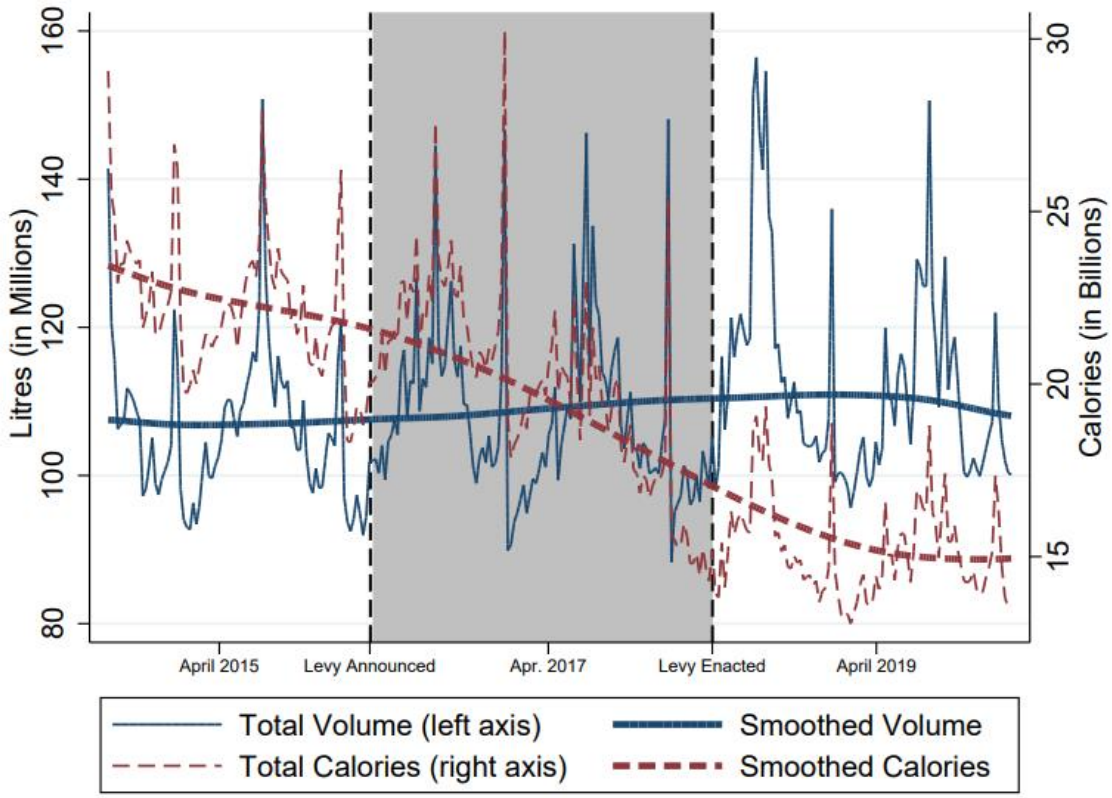
4. Non-levied brands, this category contains everything else that is not subject to the levy, either because it is in an exempt category (such as milk-based drinks or 100 percent fruit juices with no added sugar) or because it contains less than 5g of sugar before the announcement of the levy (but is not classed as a diet drink, which would be included in the category above) such as bottled water and some lemonades (which typically contain lower sugar levels).

2.11 The UK SDIL and Calorie Reduction – Summary of Impact

Figure 2.19 plots both weekly volumes and calories across the 288 weeks of the data set. The actual weekly data is influenced by seasonality (both summer and Christmas effects) hence the data is smoothed to make the longer-term trends more transparent.

Aggregated soft drink volumes (the solid blue line) are relatively consistent throughout the 288 weeks, with a very gradual increase starting to taper off towards the end of the sample period. Despite this consistent volume, calories (the dashed red line) fall significantly from circa 23 bn a week in July 2014 to circa 15 bn a week by the start of 2020.

Figure 2.19 UK Soft Drinks - weekly volume (litres) and calories

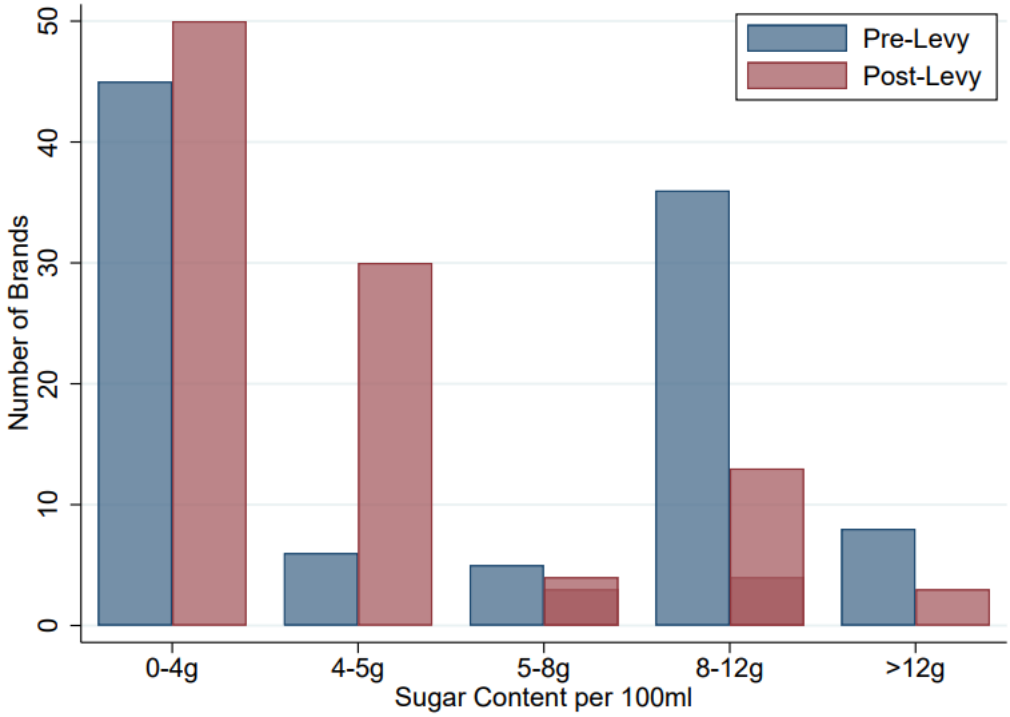


Notes: This figure shows weekly sales volume and calorie consumption for the top 100 brands in our data. Thin lines display the raw data without seasonal adjustments and are overlaid with thicker Locally Weighted Scatterplot Smoothing (LOWESS) lines.

The calorie trend in the pre-levy period is consistent with the narrative presented earlier in this chapter of an industry both recognising changing consumer attitudes and preferences towards sugar and pledging to drive calorie reduction through support for low or no added sugar variants. However, it is in the period between the levy announcement and levy implementation that the calorie reduction trend accelerates significantly with no negative impact on overall volumes (which continue to grow slowly through this period). Post implementation there is a

further continued fall in calories before the weekly smoothed trend starts to stabilise around the 15 bn weekly calorie mark. Figure 2.19 also shows that the majority of the circa 8bn reduction in weekly calories occurred prior to the levy implementation date of April 2018 and post the announcement in March 2016. This suggests the announcement of the SDIL policy triggered a supply-side response. Figure 2.20 provides more key evidence for this response. It splits the top 100 brands into one of five groups based only on sugar levels (naturally occurring or added) and compares the distribution of the brands on the day of the SDIL announcement compared to the day of the implementation some 2 years later.

Figure 2.20 Distribution of Top 100 brands by sugar content - pre and post SDIL

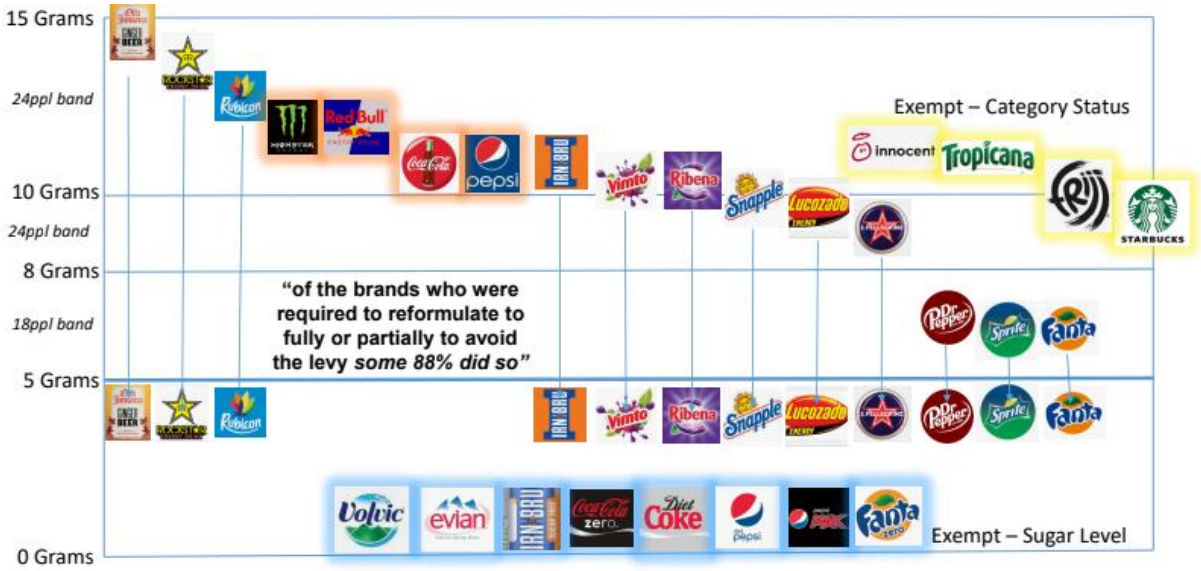


Notes: This figure shows the number of brands in the sample by sugar content. Blue bars show frequency just prior to the announcement of the levy. Red bars show frequencies after the implementation of the levy. Brands with sugar content below 5g per 100ml are levy-exempt. A levy of 18ppl is applied to brands with a sugar content between 5 and 8g per 100ml, while the levy for brands with more than 8g of sugar per 100ml is 24ppl. Note that dairy and fruit juices are exempt from the levy even if they exceed the sugar content thresholds; brands that are actually subject to the levy are highlighted in opaque red.

The number of brands sitting above the 8gram threshold level has fallen from 44 to 11. Of those 11 brands only 4 brands (the darker shaded red) would be required to pay the SDIL (the rest being either fruit juice or dairy and hence exempt). In contrast the number of brands sitting in a 4-5 grams band just below the where the SDIL threshold kicks in at 5 grams has increased by a factor of five from 6 to 30 brands.

This point can be further illustrated by Figure 2.21 which sets out the reformulation pathway of some of the more well-known global and UK soft drinks brands.

Figure 2.21 Reformulation pathway of selected UK soft drink brands



Notes: This figure illustrates sugar content and reformulation activities for 28 well-known brands. Brands that reformulated show up twice with arrows indicating the sugar reductions. Brands that chose to not reformulate or did not need to reformulate are only represented once.

Brand logos are owned by AG Barr Plc, the Coca-Cola-Company, Desnoes and Geddes Ltd, Dr Pepper Snapple Group, Group Danone, Monster Beverage Corp, Mueller Milk & Ingredients, Nestle Waters, Nichols Plc, PepsiCo, Red Bull GmbH, Starbucks Corporation, and Suntory Holdings Ltd, respectively, and were reproduced under the S30 Copyright, Designs and Patents Act 1988 (CDPA).

The blue vertical lines illustrate the movement in sugar content (y axis) between announcement and the SDIL implementation date. It clearly shows that the 5gram threshold provided both a sufficient incentive and a *clear landing point* for the desired supply-side effect.

Of the brands in this figure that could have reformulated to either fully or partially avoid the levy only 4 decided not to do so (highlighted in orange). The brands highlighted in yellow and blue were exempt from the levy to start with on a category basis or sugar level basis respectively.

Of those brands whose sugar content at announcement made them subject to the levy cost in 2 years' time, some 88% responded by taking the reformulation pathway and hence they either fully or partially avoided the SDIL from the very start of the implementation date onwards.

The four SDIL groupings allows us to present the data in summary Table 2.3.

Table 2.3 Summary data for all brands then split by the 4 SDIL groupings

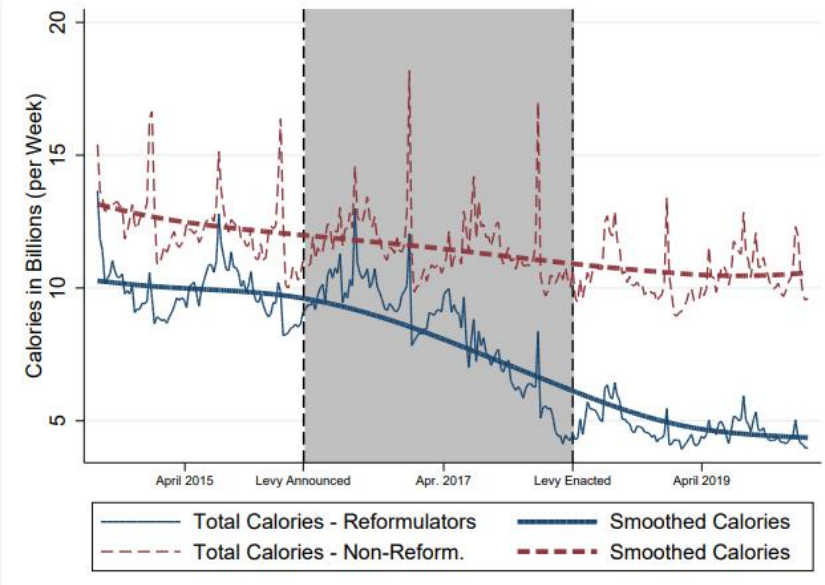
	(1)	(2)	(3)	(4)	(5)	(6)
	Weighted Category Average			Unweighted Brand Average		
	Jul 2014-Feb 2016	Mar 2016-Mar 2018	Apr 2018-Jan 2020	Jul 2014-Feb 2016	Mar 2016-Mar 2018	Apr 2018-Jan 2020
Panel A: All Brands						
£ per Litre	1.00	1.03	1.13	1.74	1.73	1.77
Volume in Mio Litres	106.18	108.16	112.40	1.09	1.09	1.12
Calories in Billions	22.21	19.91	15.20	0.23	0.20	0.15
Calories per 100ml	20.93	18.41	13.56	25.49	23.34	17.46
Observations	84	109	95	8218	10862	9500
Panel B: Levied Brands						
£ per Litre	1.31	1.41	1.97	2.15	2.13	2.51
Volume in Mio Litres	16.04	14.88	12.08	4.01	3.72	3.02
Calories in Billions	6.89	6.41	5.25	1.72	1.60	1.31
Calories per 100ml	42.96	43.08	43.48	44.25	44.25	44.25
Observations	84	109	95	336	436	380
Panel C: Reformulated Brands						
£ per Litre	1.40	1.39	1.44	1.67	1.68	1.68
Volume in Mio Litres	21.88	21.34	20.53	0.65	0.63	0.60
Calories in Billions	9.88	8.34	4.72	0.29	0.25	0.14
Calories per 100ml	45.18	38.98	23.03	42.29	37.22	20.24
Observations	84	109	95	2856	3706	3230
Panel D: Diet Brands						
£ per Litre	1.04	1.10	1.23	1.66	1.64	1.67
Volume in Mio Litres	20.65	22.96	27.89	0.90	0.96	1.16
Calories in Billions	0.13	0.17	0.22	0.01	0.01	0.01
Calories per 100ml	0.65	0.74	0.78	2.23	2.19	2.18
Observations	84	109	95	1932	2594	2280
Panel E: Non-Levied Brands						
£ per Litre	0.69	0.72	0.75	1.82	1.79	1.83
Volume in Mio Litres	47.62	48.97	51.90	1.29	1.29	1.37
Calories in Billions	5.31	4.99	5.01	0.14	0.13	0.13
Calories per 100ml	11.21	10.22	9.74	22.55	21.96	21.81
Observations	84	109	95	3108	4126	3610

Notes: This table shows the means for the sample of 100 top brands. All data are weekly from the week ending the 27th July 2014 to the 26th January 2020. The sugar levy was announced on the 16th March 2016 and was implemented on the 6th April 2018. Columns (1) to (3) show weekly category means that are weighted by volume whilst columns (4) to (6) show unweighted mean, where each brand receives the same weight regardless of volume.

This data summary confirms a total weighted average weekly fall between period (1) and (3) of some 7bn calories with just over 5bn of these coming from the group of reformulated brands. Figure 2.22 provides further compelling evidence of the role of reformulation in calorie reduction. In this chart the brands are split into reformulators (the solid blue line) and non-reformulators (the dashed red line which aggregates the remaining three groups of brands: levied; diet; and exempt). The total calories – Reformulators (solid blue line) shows the fall from circa 10bn calories a week to 5bn calories a week during the grey shaded period between announcement and implementation. We need to check that this fall is not the result of a fall in sales volume of reformulated brands. This is shown in Figure 2.23 which displays relatively

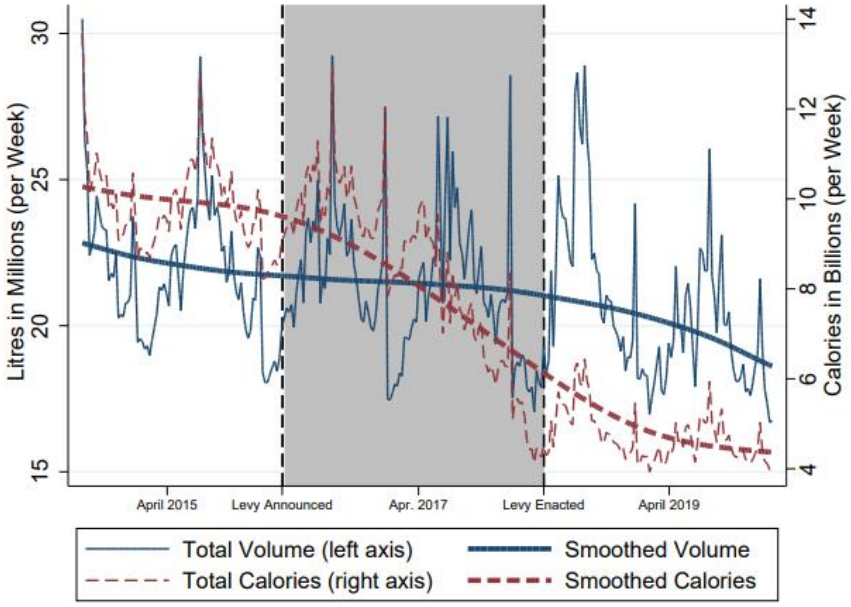
consistent volumes (blue line) throughout the grey shaded period in contrast to the marked fall in calories per week.

Figure 2.22 Calories per week reformulators (blue) compared to all others (red)



Notes: This figure shows weekly calorie consumption aggregates. The blue solid lines show calorie counts for brands that reformulated their beverages before the levy was implemented. The red dashed line shows aggregates for all other brands, i.e. levied, diet, and exempt brands. Thin lines display the raw data without seasonal adjustments and are overlaid with thicker locally weighted scatterplot smoothing (LOWESS) lines

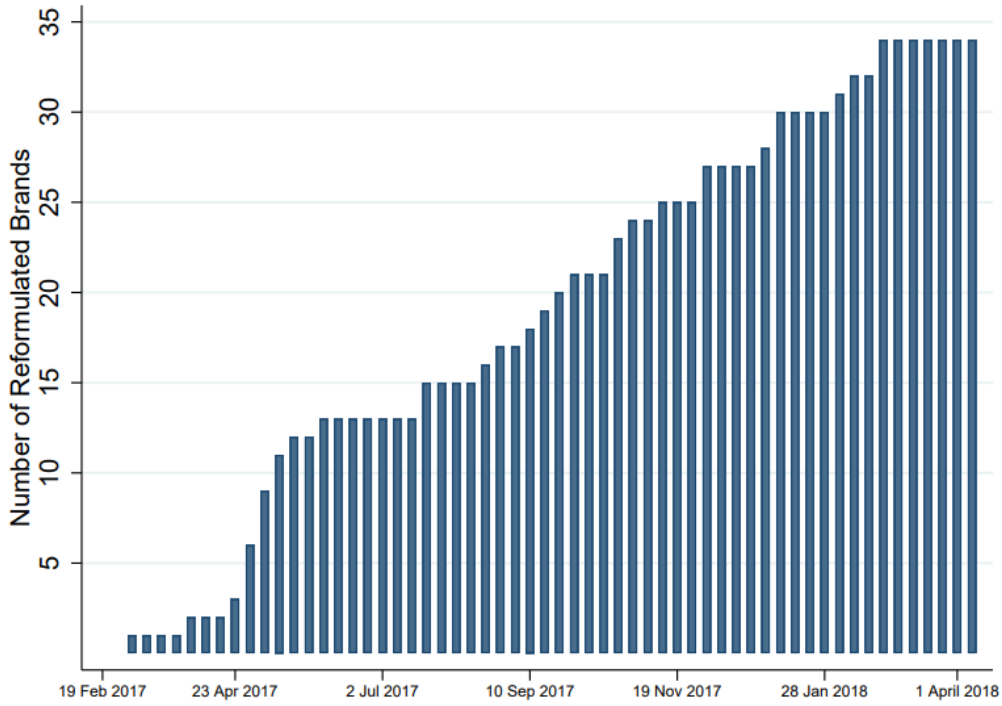
Figure 2.23 Reformulated brands total weekly volume and calories



Notes: This figure shows weekly sales volume and calorie consumption aggregates across all brands that reformulated their drinks in advance of the implementation of the levy. The thin lines display the raw data without seasonal adjustments and are overlaid with thicker locally weighted scatterplot smoothing (LOWESS) lines.

Looking beyond the LOWESS smoothing in Figure 2.23 to the actual calories per week, a consistent fall is visible which reaches a near low point of 4bn calories per week just prior to the implementation date. This is significant as it confirms the calorie reduction from reformulating brands occurred prior to when the SDIL went live. Calories from these 34 brands then build again to 6 bn per week in the summer of 2018 which was exceptionally warm in the UK (Met Office Climate Series 2018) as seasonal consumption increases before falling again to the 4bn base level. This pre-implementation, year-long decline in calories from reformulators is consistent with the spread of the actual reformulation dates across the brands. The phasing of the reformulation is shown in Figure 2.24. This near linear, year-long brand by brand reformulation process is a significant feature of the SDIL response.

Figure 2.24 Cumulative reformulation timings across the brands



Notes: This figure shows the cumulative number of brands which have reformulated their products by way of reducing their sugar content. The sugar levy was announced in March 2016 and enacted in April 2018 – with the first reformulation taking place some 12 months after announcement and the last brand reformulating at the beginning of March 2018.

2.12 Difference-in-Differences (DiD) - Event-study Specification #1

It is both helpful and important that the reformulating brands followed a staggered implementation process as it provides the opportunity to model the impact of the reformulation using a DiD event-study specification at a brand level. The 'late-reformulators' create a natural comparison group for the 'early reformulators' which support an isolation of the causal effect of reformulation on the key metrics of pricing and sales volumes, total calories and hence calories per 100ml.

Why was the reformulation staggered? The answer lies in the reformulation process described earlier in this chapter. With multi-brand producers and some multi-flavoured brands, the sheer amount of liquid development, testing, refining, artwork proofing and then bringing the new recipe into production, could only be delivered in a staggered way.

This approach also reduces the risk inherent in significant change in a manufacturing environment: it is far better from a quality control perspective to introduce new recipes into a production syrup room on a staggered 'one at a time' basis than in a large batch. Finally, there would also be an economic rationale for introduction to market once the new liquid was signed off (rather than wait until April 2018), as the significant cost of the development, testing and new packaging artwork could be quickly offset by the reduction in sugar use in the reformulated product.

Was the timing of the introduction of reformulated brands driven by systemic factors that might jeapordise the identification strategy? There is no evidence of any systemic pattern in the introduction order, which covered some 34 brands from circa 10 different soft drink producers, all of whom were working independently of each other on the reformulation challenge. It was arguably a set of non-systemic factors, such as the degree of the technical challenge, whether the brand was only bottled or owned by the producer (hence, the number of decision makers) or how much reformulation groundwork had been done prior to the announcement that drove the introduction schedule. The only co-ordinating factors were i) the SDIL implementation date that acted as a deadline and ii) the target threshold level to avoid the SDIL. This is all helpful in supporting the robustness of the chosen identification strategy and methodology.

It is also important to note that the lower sugar levels were not promoted or marketed by the reformulating brands as any form of consumer benefit. The primary reformulation objective of the brand owner was to create 'the perfect match' for the existing product rather than create

any ‘great new taste’. Even the traffic light label for sugar in a 330ml reformulated can remained red (with just the less visible numerical sugar content and % RDA altered) following a drop from 10 grams to just below the 5 grams threshold. This ‘keep the reformulation under the radar approach’[48] also helpfully ruled out any potential stockpiling by consumers in anticipating a change in recipe and the event-study results show no evidence of non-standard purchasing behaviour (such as bulk-buy cupboard loading) around the reformulation timing points.

Hence the following event-study specification was initially used to model the effects of reformulation:

$$y_{bt} = \alpha + \tau_t + \gamma_b + \sum_{\tau=0}^{m} \delta_{-\tau} Reform_{b,t-\tau} + \sum_{\tau=1}^{q} \delta_{+\tau} Reform_{b,t+\tau} + \epsilon_{bt} \quad (1)$$

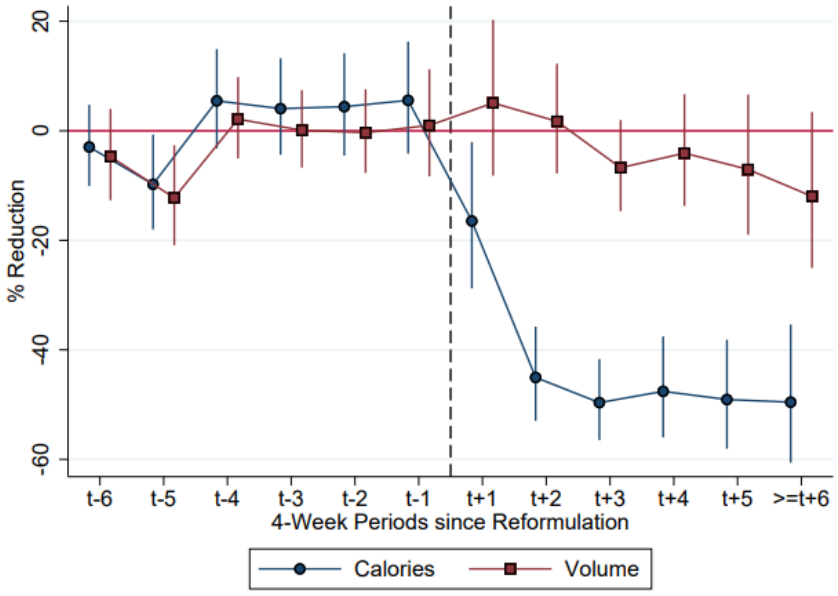
Where y_{bt} is our outcome of interest: (log) sales volumes; (log) calorie intake; price per litre; and calories per 100ml for brand b in week t. τ_t and γ_b are week and brand fixed effects, respectively. The inclusion of the full set of time fixed-effects accounts for seasonality and weather effects, whilst the brand fixed effects subsume all product specific time-invariant influences. The standard errors are adjusted for clustering at the brand level.

The validity of this approach is based on the ‘common time trend assumption’, which assumes that regardless of when the specific brand reformulated (early, middle or late in the order of the 34 brands) they were following similar sales trends and would have continued to do so in the absence of the ‘treatment’ (the reformulation of the liquid). Limiting the sample to the 34 brands (all SSBs) who reformulated also increases the credibility of this assumption.

The main coefficients of interest come from our set of 4-week leads and lags represented by the set of δ_τ coefficients. The lag coefficients document the trajectory of our main outcomes of interest after reformulation and relative to brands that have yet to reformulate, whilst the leads provide a useful check for the main identifying assumption which is more likely to be met if there are no pre-reformulation trend differences between early and late-reformulating brands.

[48] The iconic nature of IRN-BRU in Scotland meant the reformulation was anything but ‘under the radar’ and ended up being featured on both the evening TV news and front pages of the tabloid newspapers.

Figure 2.25 Effect of reformulation on sales and calories for reformulated brands.



Notes: This figure shows two sets of results corresponding to the event-study specification of equation (1). The dashed vertical line indicates the date at which a brand reformulated its product. The blue circles (offset to the left for clarity of presentation) show 4-week lead and lag coefficients along with 95% confidence intervals for (log) calories consumed. The red squares (offset to the right) show the corresponding parameters for (log) sales volumes. All estimates have been transformed into percentage changes relative to the reference period, which is $< t - 6$, i.e. prior to the six 4-week periods before a brand is reformulated.

Figure 2.25 summarises the main result from this analysis by plotting the coefficients and the 95% confidence intervals for calories (blue line with circle symbols) and sales volume (red line with square symbols). For ease of interpretation the point estimates are translated into percentage terms relative to the reference period (with the raw coefficients shown in Table A2 in the Appendix). The reference period is $< t - 6$, i.e., prior to the six 4-week periods before a brand is reformulated.

There are three key features of note in Figure 2.25. Firstly, all leads are hovering around zero suggesting that there is little in the way of differences in time trends, or anticipation behaviour. Second, there is a large drop in calorie intake in the 2 months after the reformulation point. The t+2 onwards lags suggest that in the long-run reformulation reduces calorie consumption by around 50%. The t+1 and t+2 trajectories are largely mechanical reflecting retailers selling through existing stock before only offering the reformulated version of a brand. The 50% reduction is stable in the long-run, and crucially sales volumes do not change very much: some lag coefficients are negative but none are statistically significant at the 5% level.

This event-study specification thus confirms the suggestive patterns of Figures 2.22 and 2.23 by showing that reformulation reduced calories because each litre contained fewer calories, and not because substantially fewer litres were sold. Crucially for the reformulating brands sales volumes were stable around the reformulation activity.

Table A2 in the Appendix also shows the raw δ coefficient estimates. Column (3) demonstrates that the calorie content of a typical reformulated SSB was cut by almost 21 calories per 100ml which corresponds to about a 50% reduction in calorie content. This is all consistent with a reformulation drop from 10-11 grams per 100ml to just below the 5 grams per 100ml SDIL threshold. Column (4) shows that reformulation activities were not accompanied by changes in prices, providing evidence that sales were not stabilised by making the lower sugar reformulation more attractive to shoppers by way of a lower price. No brands actively drew attention to the new product reformulations and there was no on pack communication (apart from the legal requirement to change the ingredients and nutritional panel) or advertising.

This analysis confirms the importance of reformulation activity in explaining the success of the UK SDIL in terms of calorie reductions. Reformulating brands recorded a mean weekly calorie intake of just under 10 billion calories prior to reformulation and hence the above-documented 50% effect suggests that reformulation within our top 100 brands is directly responsible for a reduction of some 4.9 billion calories per week.

Importantly, this DiD estimate needs to be interpreted as a reduction relative to a counterfactual in which no reformulation took place. That is, this estimate is net of any pre-existing trends or changes in preferences for lower calorie variants.

2.13 Difference in Differences - Event-study Specification #2

Specification #2 is based on recent research developments in econometrics and studies by, amongst others, Goodman-Bacon (2021), De Chaisemartin and d'Haultfoeuille (2020), and Callaway and Sant'Anna (2021).

This work has shown that with dynamic and heterogeneous treatment effects, traditional two-way fixed effects event-studies will be biased even under the assumption that early and late-reformulating brands were following similar outcome trends and would have continued to do so in the absence of any reformulation (the so-called 'common time trend assumption').

Hence, in order to consistently estimate the effects of reformulation on calorie intake and sales volume, specification #2 uses Sun and Abraham's (2021) 'interacted weighted' (IW) estimator which is specifically designed for this type of event-study specification.

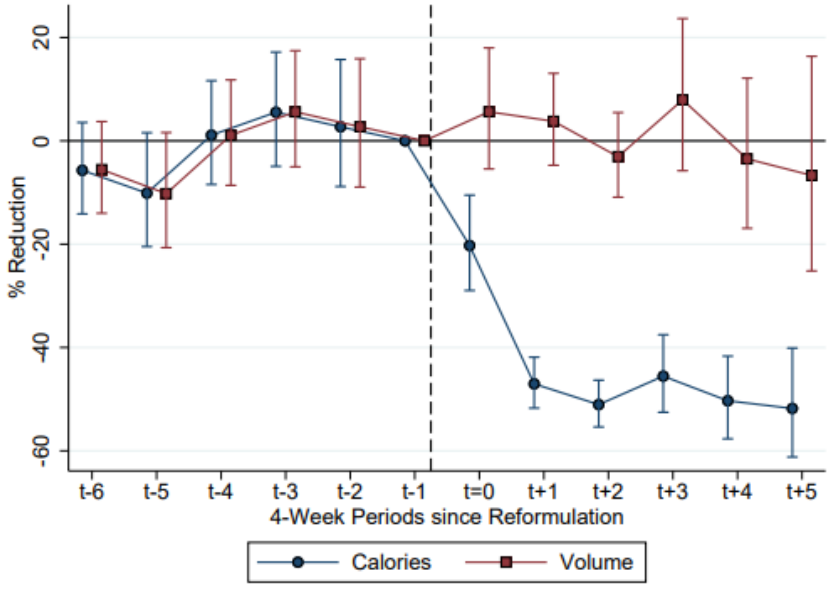
The IW estimator obtains an estimate of each cohort-specific average treatment effect $CATT_{e\ell}$ where e denotes a group ('cohorts') of brands, b, that were treated at the same time, and ℓ indicates relative time until/after the reformulation date for each brand. These lead and lag estimates are obtained by running the following specification:

$$y_{bt} = \tau_t + \gamma_b + \sum_{e \notin C} \sum_{\ell \neq -1} \delta_{e,\ell}(1\{E_b = e\} \times Reform_{b,t}^{\ell}) + \epsilon_{bt} \quad (2)$$

where relative period indicators are interacted with group indicators, but the groups from set C are excluded. This then presents two specification options, the first of which is to use levied brands which do not reformulate and hence are 'never treated' as the control group. However, there is a risk that these brands follow distinctly different sales or pricing trends which may be why they did not reformulate in the first place (for example the significantly higher penetration of the energy category amongst younger drinkers entering the soft drinks category, compared to older drinkers leaving it). Hence the preferred approach is based on Sun and Abraham's (2021) suggestion of estimating equation (2) using all except the last of the 34 reformulating brands. The IW estimator obtains weights, which are commensurate to the sample share of each group in a given period. Sun and Abraham (2021) show that these estimates, constructed as a weighted average of the $\delta_{e,\ell}$ from equation (2) avoid the contamination of lead and lag coefficients in traditional two-way fixed effect models. The results from specification #2 are shown Figure 2.26 with the full event study estimates shown in Appendix Table A3 confirming a 22-23 calorie per 100ml drop through the reformulation impact.

Whilst specification #2 as shown in Figure 2.6 is preferred as being consistent with developments in econometric methods, there are only minor differences between the results in specification #2 and the 'traditional' two-way fixed effect model used in specification #1 and shown in Figure 2.25. In terms of the overall calorie reduction contribution, the reformulation specification #1 records it as 4.9 bn calories per week compared to 5.1bn calories per week in specification #2.

Figure 2.26 Event-study Model #2 Interacted Weighted (Sun and Abraham 2021)



Notes: This figure shows results for both calories and volume corresponding to an event-study estimated using Sun and Abraham's (2021) interacted weighted estimator. The last brand reformulated at the end of April 2018 and is used as the control group. Time periods after 29 April 2018 are excluded from the analysis. The dashed vertical line indicates the date at which a brand reformulated its product. The blue circles (offset to the left for clarity of presentation) show 4-week lead and lag coefficients along with 95% confidence intervals for (log) calories consumed. The red squares (offset to the right) show the corresponding parameters for (log) sales volumes. Estimates have been transformed into percentage changes.

The rationale for this limited difference may lie in the nature of the reformulation and the quality of the work that was done by many product research and development professionals.

In specification #1 early to mid-reformulating brands such as Fanta and Dr Pepper (May 2017) would have initially been in the control group pre-reformulation or without the treatment effect, but would have then returned to the control group in a post reformulation, treated state. So, for example Barr Cola (the earliest reformulating brand in January 2017) would have been compared to a control group where Fanta was untreated, whereas IRN-BRU (a late reformulating brand in January 2018) would have been compared to a reformulated or treated Fanta within its control group. Specification #2 avoids this by removing Fanta from the control group post treatment in May 2017 and comparing the next brand to reformulate against a weighted control group of brands that have not yet been reformulated. This is clearly a more robust approach, unless the treatment effect is homogenous.

Was the quality of the reformulation work by the R&D departments so high that the effect was to create a quasi-homogenous event? Put another way, did the consumers of these brands actually realise a reformulation event had taken place?

If, in the vast majority of purchase occasions, the consumer is unaware a treatment event (reformulation) has taken place, then it will all come down to the taste of the reformulated product. The level of rigorous statistical research that takes place to achieve a taste match has been set-out earlier in this chapter, and arguably passing a TTT (an immediate comparing of liquids) is a much tougher challenge than when a drinker is simply purchasing a single product. If the consumer does not notice any difference in taste, then arguably the treatment effect becomes a homogenous event and therefore you would expect very similar results from the two specifications.

Whichever specification is chosen, both validate the key insight that the SDIL delivers over 80% of its calorie reduction through reformulation, with this reformulation and hence reduction in calories achieved *prior* to the implementation date.

2.14 UK SDIL - more reformulation than policy makers expected?

This chapter has already highlighted in Figure 2.17 that the UK Government structured the SDIL policy to encourage calorie reduction via supply-side reformulation. However, there is further evidence that this response was far greater than policy makers expected.

A requirement of the UK budgeting process is for the detail of any expected revenue receipts to be published in the Financial Statement and Budget Report (FSBR) by the Office for Budget Responsibility. This is a public domain document available on the afternoon of the budget and colloquially referred to as the 'Red Book'. This contained a forecast of treasury income from the SDIL introduction (Figure 2.27).

Figure 2.27 FSBR March 2016 Budget – SDIL revenue assumptions

Summary of impacts

Exchequer impact (£m)

2016 to 2017	2017 to 2018	2018 to 2019	2019 to 2020	2020 to 2021
-	-	+520	+500	+455

Notes: This is the expected financial impact of the SDIL as printed in the FSBR, a public domain document released immediately after the budget speech.

It is possible to compare this 3 year £1,475m forecast with the actual receipts received, which are also published into the public domain each financial year by HMRC. Over the first 3 years

of the SDIL (the period covered in the FSBR above) some £877m of SDIL (HMRC 2025) was paid by producers. Put another way, *only 59% of the expected levy benefit was realised*.

However, this is arguably one occasion where lower than expected tax receipts can be presented to the public as a clear policy success. A lower levy 'take' directly translates to a greater than expected reduction in sugar and hence calorific consumption. It is fair to surmise that the Treasury either expected fewer brands to reformulate, or more likely they expected more brands to reformulate into the 5gram to 8gram band. As we have seen in Figure 2.19 only 4 out of the 100 brands were in this mid-band at the time of SDIL implementation. These tended to be smaller volume brands, often in the premium mixer or traditional soft drink category. Based on their 'all natural' credentials these brands were either already at the top end of the mid-tier band, or were willing to drop from 10grams to just below the 8gram threshold, but were not prepared to add the artificial sweeteners that would be required to maintain a similar level of sweetness at levels less than 5grams.

With hindsight this policy expectation is perhaps understandable as a mid-band reformulation mirrors the 2013/2014 moves of Fanta, Sprite and Dr Pepper. From a commercial practitioners' perspective, the incentive to avoid the SDIL *entirely* was simply too strong, or arguably the 18p PPL levy applied to the middle band was too high.

2.15 UK SDIL – Limitations & Reformulation Beyond the Analysis Period

There are a number of DiD limitations which must be considered alongside the merits of the employed identification strategy. The first consideration is whether there are any confounding factors not captured by the methodology, factors such as the introduction of new public health regulations or nutritional improvement campaigns timed for shortly before or during the 288 week timeframe covered by the analysis.

There are two notable examples which would have arguably compromised the staggered DiD approach if they had *not* fallen outside of the announcement and implementation periods. The first is a government funded Change4Life public health campaign which encouraged healthier eating and drinking habits amongst the UK population and which specifically featured national TV advertising encouraging consumers to switch from full sugar to no added sugar soft drinks. Some £25m a year was invested by the Department of Health in this campaign between 2009 and 2012 before the annual budget fell to £10m and then £5m (UK Parliamentary Committee submissions). Whilst by the time of the Sugar Levy announcement the campaign had largely run its course, if the launch of this campaign *had* coincided with the SDIL announcement or the budget *had* remained at the initial higher levels it would have been a confounding factor in the SDIL analysis.

The second is the role of the 'Nutritional Profile Model' (NPM) and its link to any given product's 'High in Fat Salt or Sugar' (HFSS) status which arguably was the catalyst for a further round of reformulation post 2021.

There was no meaningful further reformulation from the implementation date of the SDIL in April 2018 right through to the end of the post analysis period at the beginning of 2020. It was not until after the first year of the Covid19 pandemic that three noteworthy 'events' took place.

The first and most significant relates to two new pieces of legislation - The Food Promotion and Placement (England) Regulations (passed 2021) and the Health and Care Act (passed 2022). The combined effect of these two pieces of legislation was to place significant restrictions on the display, multibuy promotion and advertising of food (and drink) that was HFSS as shown in Figure 2.28.

Figure 2.28 HFSS classification – food and drink high in fat, salt and sugar

Notes: There is no official logo for HFSS but the adoption of the acronym and the categorisation of products as HFSS or Non-HFSS based on the nutritional profile model is arguably at the heart of future UK food and drink policy.

The decision was taken to base a food or drinks HFSS categorisation for this new legislation on the Department of Health's NPM (nutritional profile model), a model which was initially developed in 2004 to determine whether a product could be advertised during children's TV scheduling. There was no policy link between the NPM and the UK SDIL and producers found themselves facing a < 5gram threshold for the SDIL whilst the NPM required a sugar content per 100ml < 4.5gram per 100ml for a drink to avoid HFSS status.

Whilst all three elements of the legislation were delayed from the initial implementation dates (instore display from April 2022 to October 2022, multibuy promotions from April 2022 to October 2025 and general advertising from October 2025 to January 2026) the overarching challenge to the soft drink industry (however frustrating the lack of alignment on the thresholds) was clear.

The ability to secure display, run volume-loading promotions and advertise on mainstream media is important to most top 100 soft drink brands, hence, from 2022 onwards all the brands analysed in this study and classed as reformulators under the SDIL taxonomy, further reformulated (or tweaked) their liquids once again to fall just below the 4.5gram NPM threshold. Whilst this further reduction was perhaps an unintentional policy intervention, it proved a highly effective way of encouraging further reformulation below the SDIL policy threshold and highlights further reformulation incentives beyond price and tax.

Clearly if the timings of these regulatory interventions had been around the time of the SDIL policy announcement through to implementation rather than post 2021 they would have represented a significant confounding factor for the staggered DiD approach.

The second reformulation event of note was the permanent introduction of a traditional regular IRN-BRU variant which was made with the pre-2018 sugar level of circa 10 grams per 100ml.

This variant was called IRN-BRU 1901[49], and in contrast to the Cola category the launch created a range which offered drinkers two no added sugar variants (Sugar Free and Xtra), a reformulated regular variant (core IRN-BRU at 4.5 grams per 100ml) and a pre-reformulation regular (1901 at 10+ grams per 100ml). It is important to note that 1901 was sold in limited formats (no large plastic bottles) and in 2024 accounted for only 4% of total brand sales. However, it does show the potential, once things have 'settled down' post transition, for brands to re-introduce higher sugar formulations to meet the needs of specific consumers.

In contrast to IRN-BRU, Pepsi Regular took the decision in March 2023 to reformulate their regular product (which had been one of the four key brands which decided not to reformulate by April 2018) – lowering the sugar level from 10.7 to 4.5 grams per 100ml. On the face of it, this represented a significant risk given the duopoly with Coca Cola who would most likely continue with a > 10 grams recipe on their core 'red can'. However, the share of the overall Pepsi business in regular in 2022 was closer to 10%, whilst the equivalent metric on Coca-Cola was 40%. 'Red Coke' also had an 8 to 1 scale advantage over 'Blue Pepsi' in the UK (Circana 2023).

The Pepsi Regular volumes 12 months after this March 2023 reformulation, indexed 65 vs the prior year – which compares unfavourably to the 98 index from Red (leviable) Coca Cola which in itself was in-line with the rest of the soft drinks market. In contrast to the SDIL data presented in this thesis this suggests a significant impact following the reformulation, *however there are many confounding factors to take into consideration*. Not least, the ppl on Regular Pepsi which arguably might be expected to fall by 28.8p per litre sold, actually increased by 27.4p per litre (or 17%) in the year after the reformulation. It is worth remembering that any brand who chooses not to reformulate at the time of a sugar tax introduction, and passes the full levy cost through to the consumer, will then operate with a permanent 'incentive' to revisit this decision. Arguably if the brand is able to successfully deliver a 'quiet reformulation' without lowering its invoice price, and at the same time grow or hold close to its current volumes, the profit impact can be transformational through a substantial reduction in the liquid COGs. This is what a brand called Rio (which now sits just outside the top 100 brands) achieved in July 2023 when it reformulated to fully avoid the SDIL having previously paid the

[49] 1901 is regarded as the year of IRN-BRU's launch in Scotland and hence this product was positioned as being made with the original 1901 recipe – which of course was 'full sugar'and actually contained slightly more sugar per 100ml than the 2018 IRN-BRU pre-reformulation.

levy since implementation in 2018. Unlike Pepsi, Rio was able to reformulate and deliver double digit volume growth in each of the subsequent years.

When it comes to new product entry it is important to determine whether the launch is actually a confounding factor or is simply part of the response to the policy intervention. For example, A.G. Barr launched 2 major new 'diet' propositions namely Rubicon Spring and IRN-BRU Xtra some six months after the announcement of the policy. These launches were a direct response to the risks presented to the business from the SDIL announcement and as such they are rightly considered as part of the policy outcomes and not confounding factors.

It was fortuitous that the 288 week period of study, covering the pre-period, SDIL announcement, SDIL implementation and post-period was arguably 'clean' from an analysis perspective and largely void of industry specific confounding factors, further policy and regulatory interventions and the big external shocks such as Covid19 and Brexit.

2.16 Conclusion – The UK SDIL and its Impact on the Supply Side

This supply side analysis completes the first half of the UK SDIL 'story'. It has added new knowledge to public health policy by providing the background from a practitioner's perspective, and then robust analysis to confirm the importance of the supply side impact in delivering substantial calorie reduction. For every six calories worth of sugar reduction that can be attributed to the SDIL, just over five of them were delivered through the reformulation response. Furthermore, this was a delivery that was achieved prior to the April 2018 implementation date and for the vast majority of brands it was 'landed' without any negative consumer reaction, or in most cases consumers even being aware it had taken place.

This analysis contains crucial insight for policy makers, stakeholders and the global food and drink industry. Some of the key implications of the insight for each of these groups will be discussed in the final section at the end of the thesis.

The third chapter of this thesis unpacks the more traditional pricing and demand side impact of the SDIL and shows how the final 'one in six' of the overall calorie reduction was achieved.

Chapter 3:

[50]

Does a Spoonful of Sugar Tax Make the Calories Go Down?
Analysis of the UK SDIL, Focusing on the Demand-Side Response

Index:

[50] Public domain photo of a shelf-talker in Sainsbury's Braehead on the 10th April 2018

3.0 Introduction

Whilst the second chapter focused on the supply side response triggered by the UK SDIL announcement, this third chapter reviews the impact the levy had on retail pricing and the more traditional method by which 'sin taxes' influence consumer demand.

It considers the initial question asked by most 'sin tax' researchers, namely whether the tax was actually fully passed through or under/over-shifted into retail pricing. The follow-up question is then what impact any change in retail price has on demand for the drink, with the assumption that soft drinks exhibit some form of price elasticities and that higher pricing curtails consumption. Applying an interrupted time series approach to the high-quality EPOS data, this study isolates the retail pricing effect of the SDIL and hence is able to calculate the contribution this element makes to overall calorie reduction.

The majority of soft drinks taxes rely on a pure demand side response to curb consumption rather than through a supply side reformulation response. Much of the literature, as detailed in the previous chapter, is concerned with pass-through and the demand response this generates. Rather than repeat the points made in the previous chapter it is perhaps helpful to consider the literature from a more holistic, meta-analysis perspective which can then serve as something of a benchmark for the findings from this study. Helpfully, the WHO commissioned a systemic review of the outcomes of SSB policies, completed by Andreyeva et al. (2022) which covered some 86 published articles of which 62 contributed to the meta-analysis.

The key metric findings of this study (at a 95% CI) were a pass-through rate of *82.2%,* a demand response in SSB sales of *-14.6%,* based on a price elasticity of *-1.59*. The study assesses the heterogeneous nature of the findings both statistically and through a range chart which shows the significant variation in findings. For example, there are 9 studies which review the pass-through and 7 studies which review the elasticity of the Berkeley local tax. The results for the pass-through vary from 7% to 65% and the elasticity from -0.05 to -7.56. Even for a national policy implementation such as the UK the pass-through findings in Scarborough et al. (2020) at 31% compare with Dubois et al. (2020) who record the pass-through at 97%.

Specifically, this chapter looks to further existing knowledge on pass-through and elasticities in a number of different ways. Firstly, the analysis shows how the pricing impact is far from uniform and instead *varies significantly between categories*, providing a key insight for future policy development. Secondly, the study shows how a detailed understanding of soft drink

market dynamics and specifically mix effects at a category, container and brand level, is required to avoid a 'trap' of accepting headline pass-through rates at face value. This study further reviews the broader retail pricing impact of the SDIL on groups where it was either avoided or they were exempt, highlighting some potential spill-over pricing effects.

Thirdly, this chapter returns to the use of Priced Marked Packs (as introduced in the first chapter) to show how brand owners themselves responded to the announcement and introduction of the SDIL when given the responsibility to set retail price points.

Finally, the study presents both the rationale for, and early data behind, a hypothesis that the pass-through outcomes associated with the launch of an SDIL will vary significantly to the outcomes associated with a number of small annual increases intended to ensure the SDIL keeps pace with inflation. In short, a combination of practitioner experience, high quality EPOS data and robust methods are combined to show why the pricing impact of SDIL taxes is heavily nuanced and complex.

Robustness and limitations are reviewed before the chapter concludes with an extrapolation methodology which calculates an estimate for the overall impact of the SDIL across the whole UK soft drinks market and not only for the Top 100 brands analysed in this study.

3.1 COGs Recap. and Consideration of the Pass-through of the SDIL

The previous chapter demonstrated how the SDIL drives a significant raw material-based cost of goods (COGs) increase should the producer continue to use ≥ 5grams per 100ml in their liquid formulation. This was demonstrated via a 2L SSB bottle example – which showed an increase in COGs of 48p per bottle (more than doubling the initial COGs) on a non-reformulated regular SSB (typically at 10grams per 100ml). The previous chapter further showed how VAT would naturally be added to the SDIL at 20% and how KPI pressure may encourage both producers and retailers to over-shift the levy to protect % margins.

Clearly the commercial discussions between suppliers (producers) and their customers (retailers and wholesalers) are highly confidential. Within FMCG, the decision by a supplier to secure a price increase from a customer typically places a strain on the trading relationship and can often lead to a period of intense negotiation with requests for both justification and mitigation. In its simplest form if the additional price paid by the shopper for a soft drink is say 10p, then both the retailer and supplier will want to maximise their share of that 10p. It is

also important to remember the role that VAT plays in soft drinks with HMRC automatically gaining 1.66p of additional VAT for every 10p increase in the retail price point. There is unfortunately no negotiation with HMRC.

The outcome of the supplier / retailer negotiations typically depends on the relative balance of buying vs selling 'power'. The stronger the equity, uniqueness or higher the market share of the brand the more this will sit with the supplier. In contrast, the higher the market share of the retailer the more leverage they will have over their suppliers. Regardless of where this balance may lie, for any change in retail pricing *a researcher simply cannot be certain of the level of COGs increase that was potentially passed from the producer to their customer.*

From experience, FMCG soft drink producers will run an annual budgeting process and look to fix their COGs (both labour and raw materials) for at least a 12month period in advance. This tends to lead to an annual price increase process with customers – often centred on a calendar year basis with for example the 2015 pricing being shared in October 2014 and effective from January 2015.

It is important to remember than only 4 major brands were liable for the SDIL at the April 2018 point of implementation. Some of these brands may have delayed annual increases (and hence other cost price inflationary pressures) to tie in with the SDIL date, whilst others may have treated the increase as a discrete event. The timing of the SDIL implementation date was known by producers and retailers some two years in advance, and the exact COGs increase was transparent to all.

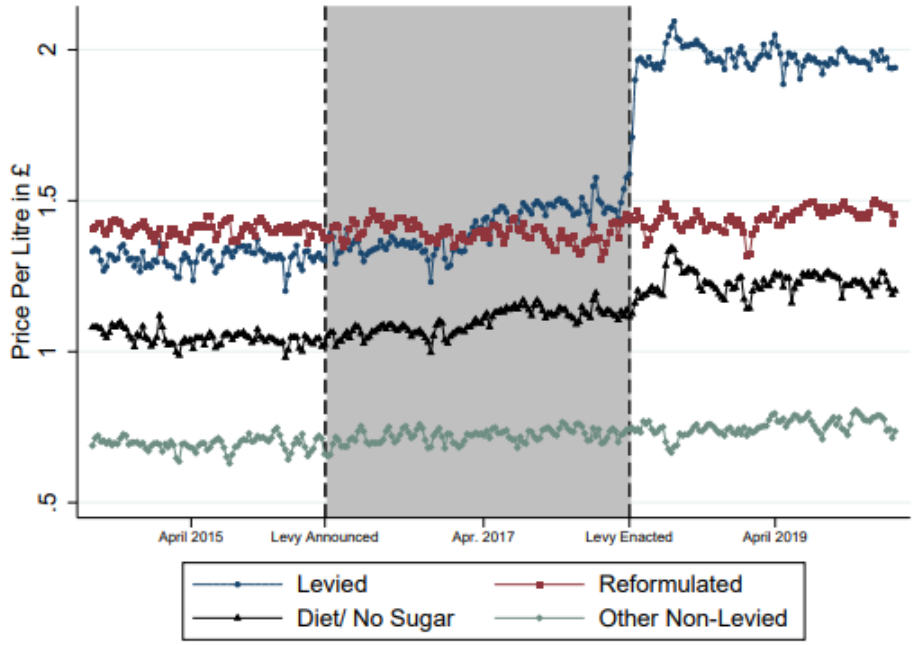
Experience of supplier / retailer relationships, coupled with the uniqueness of the SDIL introduction, would lead to the following 'fair pass-through' hypothesis. Namely, that on the four leviable brands the exact levy amount was fully passed on to customers on or around the SDIL go live date, who accepted the increase and passed the exact amount of the increase plus VAT onto their shoppers. Other inflationary pressure may also have been included in this cost increase or they might have been covered in an annual increase taken earlier in the year.

Whilst commercial sensitivities mean we will never be able to definitively prove this hypothesis, what we can of course be certain about, and hence analyse, are the EPOS recorded movement in retail pricing on a ppl basis and the impact it had on consumer demand.

3.2 Impact on Retail Price Trends by SDIL Category

We can follow retail price movements as measured by an aggregated price per litre (ppl) through a graphical examination of the long-term pricing trends (Figure 3.1).

Figure 3.1 Long term average EPOS recorded ppl for each of the 4 SDIL groups



Notes: This figure shows the weekly average price per litre (in £) for four categories of beverages: levied soft drinks, brands which reformulated, diet and no sugar products which attract zero levy, and levy exempt products (see Chapter 2.9 for full definitions). Within each category, the average price per litre is volume-weighted.

For each of the four SDIL response categories an average weekly price paid per litre by shoppers is calculated by simply dividing the aggregated retail turnover of all brands within the category by the aggregated volume of the same brands. The initial ppl's in week 1 of 288 (w/e 27th July 2014) are represented by the red (reformulated @ £1.41), blue (levied @ £1.34), black (diet @£1.08) and teal (other non-levied @£0.68) points closest to the Y axis. The relatively low level of the other non-levied ppl reflects the scale of water @£0.57 ppl relative to other non-levied (exempt) product groups such as Fruit Juice @ £1.34 ppl.

Of particular interest is the movement in the blue line levied brands at the point of implementation. The line very noticeably increases from circa £1.50 per litre to circa £2.00 per litre, which at face value is clearly contrary to a 'fair pass-through' hypothesis and suggests a significant over-shift in a 28.8p per litre tax. There is no significant or structural increase in the price of the reformulated brands, nor in the movement of exempt brands. There does

however seem to be an increase in the price of diet brands (the black line) which both steps up at the point of implementation and has a peak for a number of weeks across the 2018 summer. This specific point will be examined later in the chapter.

3.3 Methodology for Measuring Pass-through and Demand Response

The method chosen to analyse the effect of the SDIL on retail pricing, volume and calories is a structural break technique. This approach is commonly used in macroeconomics, but also lends itself to this time series, implementation date type of setting.

Consideration was also given to using non-levied products as a control-group to create another difference in difference approach, however this was rejected on the basis of both the known reformulation activity inducing a confounding variation and the change in retail pricing in the Diet group potentially being indicative of spill-over effects.

The interrupted time series approach has been applied in a number of studies, including Evans et al. (2019) where it was used to evaluate the reformulation of a prescribed opioid, and Jaychandran et al. (2010) where it measured the impact of the introduction of sulfa drugs in the US. The approach resembles a parametric regression discontinuity design (Hahn, et al., 2001) with time as the running variable and the introduction of the levy implementation date as the 'treatment effect'. The analysis starts with a structural break test by running a model of the following form:

$$y_{ct}^{res} = \alpha + \beta D_t(\tau) + \epsilon_{ct} \quad (1)$$

y_{ct}^{res} is the outcome of interest (price per litre) for each of the four SDIL categories c in week t. This outcome is regressed on an indicator $D_t(\tau)$ that is equal to 1 for week τ and all subsequent weeks and zero otherwise. There are 288 weeks in the sample period and hence for each of the 288 estimates the hypothesis that β = 0 is tested, with the corresponding F-statistic looking for the highest structural break in levels. The top 5 'breaks' are shown in Table 3.1.

Given the importance of seasonality in soft drink sales, and the associated risk of mistaking a seasonal event for a break point, the outcomes are initially de-seasonalised by regressing them on controls for weather (temperature and rainfall), a set of 'week of the year fixed effects' and

also a set of dummies for the 5 weeks around the Christmas trading period. Christmas is a particularly hard period to control for as the shopping spikes are marked whilst the actual Christmas day of the week (and sometimes week of the year) naturally changes each year. It is also a trading period which sees consumers bulk purchase to actively stock up on soft drinks (bringing forward purchasing but not necessarily consumption) whilst retail shopping patterns are also impacted by changes in store opening hours.

Table 3.1 Top 5 structural level breaks by SDIL category

Panel A: Pricing (£ per litre)

	Levied		Reformulated		Diet/ Zero-Sugar		Levy-Exempt	
Rank	Date	F-Stat	Date	F-Stat	Date	F-Stat	Date	F-Stat
1	15apr2018	2005.5	24feb2019	100.3	22apr2018	273.8	17feb2019	81.5
2	08apr2018	1885.3	17feb2019	98.9	15apr2018	270.9	24feb2019	81.3
3	22apr2018	1820.3	10feb2019	91.0	06may2018	266.2	22may2016	80.2
4	29apr2018	1551.7	03feb2019	78.4	29apr2018	265.8	08may2016	79.9
5	01apr2018	1544.4	27jan2019	51.2	13may2018	263.3	01may2016	79.7

Panel B: Volume (Million Litres)

	Levied		Reformulated		Diet/ Zero-Sugar		Levy-Exempt	
Rank	Date	F-Stat	Date	F-Stat	Date	F-Stat	Date	F-Stat
1	08apr2018	316.5	24feb2019	89.9	04feb2018	287.1	07jan2018	18.3
2	01apr2018	314.4	17feb2019	87.4	11feb2018	283.1	21jan2018	17.8
3	15apr2018	311.8	03feb2019	83.0	12aug2018	278.8	14jan2018	17.8
4	25mar2018	307.4	10feb2019	82.3	14jan2018	276.2	28jan2018	17.4
5	22apr2018	299.2	27jan2019	76.0	18feb2018	273.0	16jul2017	17.0

Panel C: Calories (Billions)

	Levied		Reformulated		Diet/ Zero-Sugar		Levy-Exempt	
Rank	Date	F-Stat	Date	F-Stat	Date	F-Stat	Date	F-Stat
1	08apr2018	300.0	02jul2017	459.9	04feb2018	240.8	26jun2016	27.7
2	01apr2018	299.6	16jul2017	442.5	11feb2018	237.8	27nov201	27.4
3	15apr2018	296.5	23jul2017	440.8	14jan2018	232.3	19jun2016	27.3
4	25mar2018	293.9	11jun2017	436.3	18feb2018	229.7	13jul2016	27.3
5	22apr2018	284.6	25jun2017	429.5	28jan2018	229.5	04dec2016	27.2

Notes: This table shows the results of a test for breaks in our outcomes of interest. Structural breaks are estimated as outlined in equation (1). This table reports the 5 weeks with the largest F-statistic.

The SDIL was implemented on the 6th April 2018 and panel A in Table 1 identifies the top 5 structural breaks as all occurring around this date (a week before, the actual week and the 3 weeks after). This is clearly consistent with the graphical evidence of Figure 3.1. Significantly the panels B and C show that the break in price was associated with breaks in volume and hence

calories. With the breakpoint both graphically and structurally identified it was then possible to model the impact of the levy on retail prices as a function of an overall trend and the identified level shift:

$$y_{ct}^{res} = \alpha + f(Time_t) + \beta Post_t + \epsilon_{ct} \quad (2)$$

The dependent variable y_{ct}^{res} is the volume-weighted, seasonally-adjusted average price for brands in the four different groups – with the group 'levied' brands being of particular interest given it is where one would expect to see any pass-through of the levy. The weekly EPOS data is 'week ending' based on Sunday night, whereas the actual implementation date was the 6th April (unusually a Friday) hence the $Time_t$ as a continuous variable, was centred around the week ending April 1st 2018. The preferred specification is a parsimonious, quadratic setup where $Post_t$ is a dummy variable which is equal to one for weeks ending after April 6th 2018. The coefficient of interest is β which measures the average price increase once the levy is put into effect.

A similar model is also estimated which in addition to the break in levels also allows for a break in trends:

$$y_{ct}^{res} = \alpha + f(Time_t) + \beta Post_t + \gamma Post_t \times f(Time_t) + \epsilon_{ct} \quad (3)$$

Here the interest is in both β and γ where the latter coefficient may pick up a change in the slope of pricing after the introduction of the levy. The jump or 'step-change' in pricing in Figure 3.1 suggest that the increase in retail price for the leviable brands was almost instantaneous hence it is reasonable to expect the parsimonious model in equation 2 to be preferable and for β to be highly significant in both specifications.

Clearly there are limitations which must be considered with this type approach, specifically whether there are any confounding factors which may have caused or contributed to the clear pricing shift on leviable brands visible in Figure 3.1 or identified in Table 3.1. For example, Section 2.7 shows how the effect of the SDIL at the highest 24p per litre rate is the equivalent of a near six-fold increase in the price of sugar used in a leviable drink. Can we be sure that there was no dramatic increase in sugar costs that just happened to coincide with the SDIL implementation date? An examination of sugar costs throughout the 2016 – 2018 period (ONS Sugar CPI Time Series 1971-2025) confirms that pricing was stable and we can rule out any

confounding increase in this key raw ingredient concurrent with the SDIL announcement and implementation.

We must also consider whether there were any anticipation effects from either retailers or consumers that could have impacted the supply chain. If retailers, or a concerted effort by consumers, saw the stockpiling of significant quantities of those products who had either chosen not to reformulate (such as Regular Coca-Cola which typically carries a 6 – 12 month shelf life) or the old full sugar formulations of the reformulators (such as Regular IRN-BRU, again carrying a 6 – 12 months shelf life) just prior to the SDIL implementation, it could weaken the validity of the approach and the sharpness of the structural break.

Practitioner experience of both the supply chain and the manner in which producers and retailers manage cost pricing would lead to the hypothesis that anticipatory effects are highly unlikely in this scenario. Given the heavily publicised implementation date it is not surprising that we see such a sharp pricing response on leviable brands concurrent with the week of the SDIL introduction. As the first picture at the start of this chapter shows, retailers actually produced point of sale material citing the SDIL introduction to explain why they had moved prices on leviable products within this specific week.

Soft drinks are also largely water and as such represent a relatively bulky, low value per litre item compared to other beverages such as wine or spirits. This makes the decision to produce and store additional stock to support anticipatory practices both physically challenging and highly costly to execute. The soft drink supply chain is 'lean' with producers and retailers relying on 'just in time' production and frequent deliveries, rather than having the capacity to carry weeks of stock in the supply chain.

3.4 Main Result – Significant Tax Over-shifting of the UK SDIL

The main results of the analysis are reported in Table 3.2, where Panel A suggests that the implementation of the SDIL shifted the price of the leviable products upwards by between 48ppl and 50ppl (column 1 and column 2) a level which is consistent with the graphical representation in Figure 3.1. This leads to the headline, *'28.8p sugar tax over-shifted by (almost) a factor of 2'*.

However, such a headline would arguably be misleading and to understand the way the SDIL is passed through requires a much more granular level of analysis. It is important to remember that the outcome measure in Table 3.2 represents a volume-weighted, average price per litre of product sold, for each of the four SDIL categories.

Table 3.2 Levy effects on pricing, sales volumes, and calorie intake – aggregate level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Effects on Pricing (Consumer Outlay)								
	Levied		Reformulated		Diet		Levy-Exempt	
$Post_t$	0.484***	0.507***	0.024*	0.024**	0.082***	0.098***	-0.012	-0.008
	(0.027)	(0.023)	(0.014)	(0.012)	(0.019)	(0.018)	(0.010)	(0.009)
$Post_t \times Time_t$		-0.001***		0.001***		-0.000*		0.000*
		(0.000)		(0.000)		(0.000)		(0.000)
Panel B: Effects on (Log) Volume								
	Levied		Reformulated		Diet		Levy-Exempt	
$Post_t$	-0.202***	-0.201***	0.014	0.018	0.060***	0.073***	0.043***	0.042***
	(0.018)	(0.015)	(0.017)	(0.016)	(0.019)	(0.016)	(0.016)	(0.015)
$Post_t \times Time_t$		0.002***		-0.001**		-0.000		-0.000*
		(0.000)		(0.000)		(0.000)		(0.000)
Panel C: Effects on (Log) Calories								
	Levied		Reformulated		Diet		Levy-Exempt	
$Post_t$	-0.198***	-0.196***	-0.234***	-0.324***	0.069**	0.087***	0.021	0.048***
	(0.018)	(0.015)	(0.078)	(0.058)	(0.027)	(0.023)	(0.015)	(0.014)
$Post_t \times Time_t$		0.002***		0.002***		-0.001***		0.001***
		(0.000)		(0.001)		(0.000)		(0.000)
R^2	0.972	0.976	0.373	0.409	0.830	0.837	0.843	0.836
N	288	288	288	288	288	288	288	288

Notes: Newey-West standard errors allowing for autocorrelation in the error term for up to two lags are reported in parentheses. $*$ p < 0.10, $**$ p < 0.05, $***$ p < 0.01. This table shows regression results of two structural break models as outlined by equations (2) and (3). All data are weekly national aggregates weighted by sales volume. R-Squared refers to the pricing regression (Panel A).

Variable *Post t* measures the structural break in terms of price (actual pence) and volume / calories which are expressed in logs to provide a read of the percentage change. For the group of levied brands, we see under the initial specification a 48.4p increase in price per litre and a 20% reduction in volumes sold – which not surprisingly corresponds to a similar reduction in calories. Variable *Post t x Time t* measures for a break in trends and here there is no statistically significant level of response across any of the four categories for any of the variables. This result is not surprising given the construct of the SDIL and is consistent with the graphical evidence in Figure 3.1.

Within the leviable category there will be significant mix effects which can *create an illusion of over-shifting* at an aggregated level. These mix effects can be reviewed at three main levels of influence, namely at a Category, Container and Brand level.

3.5 Mix Effects and Contrasting Leviable Segment Impacts

It has previously been noted that the four main levied brands were Regular Coca-Cola, Regular Pepsi, Monster Energy and Red-Bull. The first two of these brands sit within the cola category and serve economists as an example of the classic duopoly. Between them, these two brands account for some 98% of all cola retail spend and 94% of all cola litres consumed (Circana EPOS 2015).

The Red Bull and Monster brands represent a similar duopoly within the energy drinks category, although there are some key differences between the two categories.

The first is the consumer motivation for purchase. A cola will be drunk for a combination of its pleasant taste, the hydration benefit and as a mild 'pick me up'. This comes from a combination of added caffeine (around 10mg per 100ml) and added sugar (10-11grams per 100ml in the regular versions). An Energy drink is purchased for the same three benefits, but with significantly more importance placed on the functional benefit. This typically comes from a higher level of sugar (11-12 grams per 100ml) and a much higher level of caffeine (32mg per 100ml) alongside other functional ingredients.

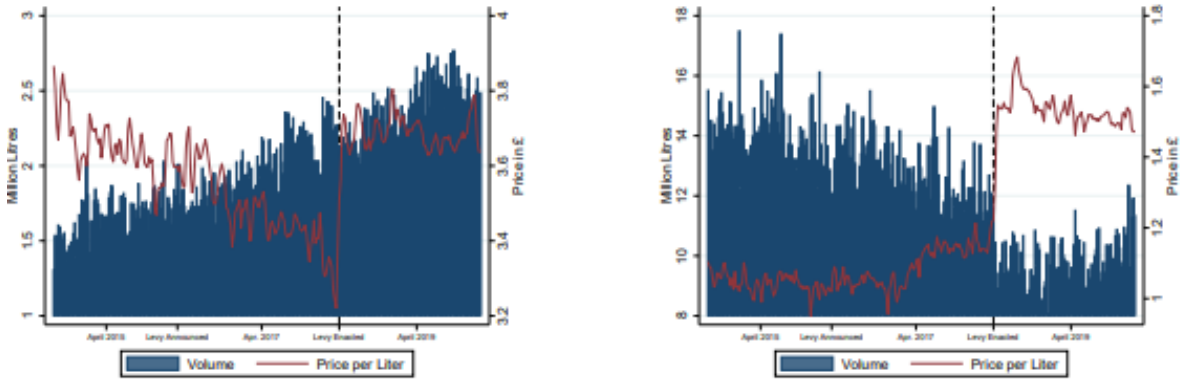
The second difference is the way the product is consumed. Cola is sold in both drink-now formats (cans and small bottles), but also in large 2L bottles and 24 x 330ml can multipacks for storing in the home, and then sharing at family meal times or at social gatherings. These take-home containers tend to have a substantially lower ppl than drink-now formats. In contrast energy drinks are largely bought chilled in single cans for immediate need and 'on the go' consumption.

These two differences contribute to create a fundamentally different ppl pricing structure for cola compared to energy drinks. In the 12 months prior to April 2018 the average ppl on regular cola (Red Coke and Blue Pepsi combined) was £1.14. In contrast the average combined retail ppl on Red Bull and Monster was circa 3x this level at £3.41 (Circana 2018). Hence if there was a different response from each of the segments to the levy, *which altered the ratio of cola*

sales to energy sales, it would mechanically drive a change in the average ppl across the combined levied category.

It is therefore important to split the analysis of the levied category into leviable energy and leviable cola. These results are shown in Figure 3.2 and Table 3.3. Whilst this analysis now starts to consider the demand impacts of these category specific retail price increases, and does so ahead of the more detailed analysis of the full results in section 3.10 – it is necessary to do so to understand how the mix effects drive the illusion of significant tax over-shifting.

Figure 3.2 Levied category split leviable energy and leviable cola



(a) Levied Energy Brands **(b) Levied Cola Brands**

Notes: The red lines show the weekly average price per litre (in £) measured on the right y-axis, alongside weekly sales volumes (in million litres) shown by the blue bars and measured on the left y-axis. Panel (a) shows both measures for levied sports and energy drinks, whereas Panel (b) displays measures for levied colas. Price data are weighted by volume sales in both charts.

Table 3.3 Pass-through rates for leviable energy and leviable cola

	(1)	(2)	(3)	(4)
	Levied Energy		Levied Colas	
$Post_t$	0.331***	0.320***	0.393***	0.413***
	(0.017)	(0.014)	(0.017)	(0.016)
$Post_t \times Time_t$		0.002***		-0.001***
		(0.000)		(0.000)
R^2	0.994	0.994	0.955	0.957
N	576	576	576	576

Notes: Heteroscedasticity-robust standard errors in parentheses. $*$ p < 0.10, $**$ p < 0.05, $***$ p < 0.01 This table shows regression results of two structural break models as outlined by equations (3) and (4). The unit of observation for this specification is the brand-week, all data are unweighted. The sample was limited to levied brands and split by beverage type.

The blue shaded weekly bars in Figure 3.2 suggest that the levied energy brands growth trajectory was not impacted by the SDIL introduction and the associated retail price increase.

In short, levied energy brands did not 'miss a beat' in their continued almost linear growth trend. In contrast there was a marked drop in levied cola volumes at the time of the structural retail price increase. A simple category comparison shows that levied cola volumes fell by 24.7% in the year following the SDIL implementation whilst levied energy volumes grew by 9.5% (Circana 2019).

Why was there such a heterogeneous response to the levy? There are probably two logical explanations for the difference. The first (based on consumer research) is simply that drinkers see the high sugar content in an energy drink as an integral part of the proposition. This is the key reason why, at the time of the SDIL implementation, levied energy versions accounted for circa three quarters of the sales of the parent brands, whereas for levied colas the ratio was reversed with diet versions dominating. A shopper facing a significant price increase on a regular energy drink may see a non-levied no added sugar energy drink as a poor substitute. In contrast, a cola drinker may prefer a full sugar product but see a no added sugar cola as a more acceptable substitute, particularly if sold at lower price.

Secondly, whereas on a per ml basis the levy COGs impact was the same for cola and energy brands, the % increase in retail price this represented on pass-through was significantly different. A 330ml regular can of cola was selling for an average of 65p at the time of the introduction, and hence a full pass-through (levy + VAT) would see the retail price increase by 9.6p to 75p, a 15% increase. In contrast a 250ml Red Bull selling at £1.19 would only see a 6% retail increase (moving to £1.26).

This analysis starts the process of unpacking the '50p over-shifting' headline. Table 3.3 shows the *actual* increase was 32p on levied energy (a marginal 11% over-shifting) and 41.3p on levied colas (a 43% over-shifting).

3.6 Container Level – Mix Effects

Sitting below the category level mix effects are a series of container mix effects which also contribute to a headline of significant tax over-shifting. Levied cola brands are typically available for purchase in a range of pack sizes and formats, from 250ml cans through to 3L bottles, as well as singles and multipacks. Again, the structure of the SDIL means the relative % price increase is typically greater for larger packs (say 2L) than smaller packs (a 330ml can). We saw in the earlier calculation the 'higher' 15% increase in the retail price of a single can of

levied cola. However, this compares with the 58% increase in the retail price of a £1 promoted 2L bottle (on full pass-through) as demonstrated in the previous chapter.

Given the higher retail ppl on 330ml single cans (£1.95) compared to the 2L promoted bottle (£0.50) and the likely impact of the different % increases, the natural expectation would be to see growth in the volume ratio of drink-now (smaller) containers relative to take-home (larger) containers. This then naturally triggers another mechanical mix effect given the significant difference in the ppl.

We can see this effect in Table 3.4 which splits both levied groups into drink-now and take-home product groupings. Even though the structural retail price increase is higher on a ppl basis on drink-now Cola, the relative % price increase impact means that the volume impact on take-home leviable cola is at nearly twice the rate of drink-now cola. We also see the headline leviable cola pass-through rate of 41.3p falls to 37.2p (take-home cola) and 41p (drink-now cola) respectively.

Table 3.4 Take-home and drink-now splits in leviable categories

Panel A: Levied Brands								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Take-Home Sizes				Drink-Now Sizes			
	Colas		Energy		Colas		Energy	
	Price	Volume	Price	Volume	Price	Volume	Price	Volume
$Post_t$	0.372***	-0.258***	0.387***	-0.139***	0.410***	-0.132***	0.279***	-0.001
	(0.026)	(0.026)	(0.043)	(0.032)	(0.022)	(0.016)	(0.020)	(0.021)
Mean:	0.92	8.62	2.58	0.43	2.28	2.06	3.47	1.64
R^2	0.763	0.315	0.960	0.815	0.743	0.838	0.985	0.734
N	288	288	288	288	288	288	288	288

Notes: Newey-West standard errors allowing for autocorrelation in the error term for up to two lags are reported in parentheses. $*$ p < 0.10, $**$ p < 0.05, $***$ p < 0.01 This table shows regression results of two structural break models as outlined by equation (3). All data are weekly national aggregates weighted by sales volume. Mean gives the weekly average price and volume for March 2018, the month prior to the implementation of the levy. Price is in £, volume in million litres. Both measures are seasonally adjusted. The regression analysis uses the natural logarithm of volume as the dependent variable.

From a robustness perspective it is important to check that the container or package size mix effects seen in the leviable category were not underlying trends in the overall soft drink category and can't be found other non-leviable categories such as water. It is in the regular Cola brands take home packs, such as 2L bottles, where we see the greatest % retail price impact of the SDIL and certainly much more significant than in the equivalent regular cola drink now packs which already sell at a ppl premium. It is this impact which leads to a post

levy change in the ratio of drink now to take home sales volumes, and it is this ratio change which causes the ppl to mechanically increase.

This mix effect can be clearly seen from the EPOS data with drink now, as a % of leviable cola volumes, increasing from 16.9% in the year before announcement to 18.4% during the 2-year gap between announcement and implementation then followed by a 22.0% share of volume in the year post April 2018.

If water (which was non-leviable and hence saw no increase in price in April 2018) followed similar patterns it could be argued that the container size mix effect was caused by other factors other than the SDIL. However, analysis of the ratio between drink now and take home packs in water confirms that, unlike leviable cola, there was no similar increase in drink now volumes relative to take home volumes across the overall 4 year timeframe.

3.7 Brand Level – Mix Effects

The commercial sensitivity and agreement with the data providers, prevents the sharing of a full 'by brand' analysis in this thesis, however the brand mix concept can be clearly outlined with higher-level data.

Whilst 'Red Coca Cola' and 'Blue Pepsi' can be considered close competitors for each other, the data shows a long-term differential in the average selling ppl. In the 12 months prior to the levy implementation, regular Coca Cola in the UK sold at an average price of £1.22 a litre whilst regular Pepsi sold at an average £0.87 per litre. Whilst some of this delta can be explained by pack size mix effects, on a like for like pack basis, Coca Cola was typically sold at a premium to Pepsi.

The SDIL implementation is a disruptive market event, not only in terms of cost and retail pricing, but also in terms of how much marketing or promotional support producers and retailers may place behind specific brands. In an expandable consumption category such as soft drinks, promotions (which lower the average ppl) are key to driving volume. In the year post the SDIL implementation, the regular Coca Cola ppl increased by 31% whilst the regular Pepsi ppl increased by 51% - narrowing the differential both in nominal and % terms. This, alongside non-pricing factors, is likely to have been responsible for the very different

performance of the brands in the first-year post implementation, when regular Coca Cola volumes fell by 19% and Pepsi volumes fell by 47% (Circana 2019). The effect of the higher ppl brand increasing share of total leviable sales drives a mechanical higher overall ppl in levied cola, adding a third mix effect to complete the illusion of over-shifting.

3.8 Pass-through in Non-levied Categories

The analysis in Table 3.2 also details any price changes that occurred in non-levied categories at the same time as the SDIL implementation.

As perhaps expected, there is no statistically significant price response from exempt categories as 'nothing had changed' for the producer and hence there would be no rationale to present customers with a price increase. The structural break test in Table 3.1 also shows this group to be characterised by very stable pricing and as it is dominated by still bottled water, it is not likely to be considered as a close substitute for levied cola or energy brands. Consumer usage and attitudes research (AGB 2016) identifies a very different purchase motivation and need state for plain water (hydration) compared to the leviable brands (high flavour taste, carbonation, energy from sugar and a functional caffeine effect).

Whilst the same 'nothing has changed' comments could be said to apply to diet brands, both the graphical representation and structural break test indicate a structural pricing change shortly after the levy implementation. The analysis confirms this to be a statistically significant increase of 8 to 10 ppl in the diet grouping at a time when know there was no SDIL driven changes in COGs.

There are two logical explanations for why diet products moved in retail price at this time. The first is that the diet variant of a regular drink can be considered as its closest possible substitute. Put simply, of all the soft drink brands on the market IRN-BRU Xtra (no added sugar) will have the closest taste and brand presentation to regular IRN-BRU. There is a simple economic argument that if the regular variant increases in price it is natural to expect the diet variant to at least partially follow. An example of this close substitution concept is perhaps best demonstrated by the changes in Coca Cola Zero (Figure 3.3).

Figure 3.3 Coca Cola and Coca Cola Zero brand get-up evolution

Notes: Coca-Cola Zero (and Zero Sugar) can get-up in 2006, 2016 and 2021 compared to the 2021 Regular proposition.

Figure 3.3 provides clear visual evidence of how the get-up of Coca-Cola Zero has been developed over-time to make it a much closer proposition to the 'Original' variant. An optimal pricing strategy for a brand owner could be to increase the price of the exempt variant in parallel to a (levy-induced) increase in the price of the closest substitutes. In the six months post implementation the average ppl of Coca-Cola Zero increased from £1.15 to £1.24 an 8.3% increase (Circana 2018).

The second explanation is that general inflation, RPI was 4% in Jan 2018, was driving COGs increases across all products and given the timing of a required SDIL increase was well known, a further general price increase was timed to both mitigate these cost pressures, and to coincide with the levy-based increase. It is not possible to prove this either way and it could well be a combination of these factors that resulted in a retail price increase in the diet grouping.

Looking carefully at Figure 3.1, there is a small but noticeable spike in diet pricing some 3 months after the SDIL went live. This is arguably a great example of an unexpected confounding factor. Whilst the analysis is controlled for seasonality, the weather in July 2018 was exceptional, with the second warmest July on record – (UK Met Office Time Series Climate Averages 2014 - 2020) and this naturally drives consumption of drink-now products ahead of take-home products generating a modest positive mix ppl benefit. However, this heatwave also coincided with a well reported shortage of Co2, a core ingredient in fizzy drinks (BBC news / business – Co2 shortage 27/06/2018). This forced producers to do two things, firstly, to cancel all the planned bulk buy promotions in supermarkets, an action which naturally

raises the average PPL, and secondly, to prioritise the Co2 that was available into the production of smaller drink-now packs (which both require less Co2 and contribute a much higher profit per litre sold). These combine to create the small blip.

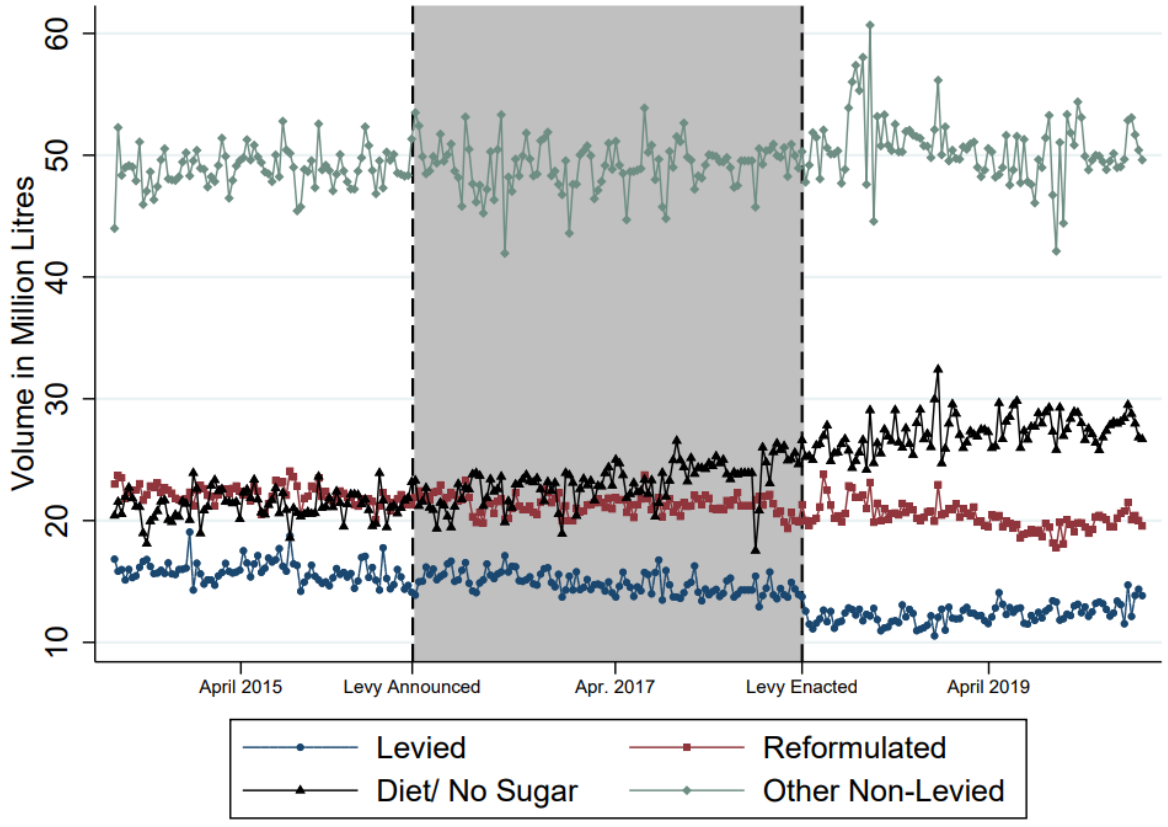
Finally, for the reformulated group we cannot reject a null hypothesis of no price change at the 1% significance level, albeit the analysis shows this to be a 2.4ppl increase, which is relatively small and could be reflective of general cost pressures. It is worth noting that whilst the reformulation process will have been costly for producers depending on the type of replacement sweetener system chosen[51] there would be significant cost savings available from the reduced usage of sugar.

[51] At the time of reformulation there was typically no COGs saving available if the sugar was replaced with natural sweeteners.

3.9 Volume and Calorie Impacts for the 4 SDIL Categories

With a better understanding of the headline 50ppl pass-through rate, we can now review the impact of the retail price moves on sales volumes (and hence calories) within each of the different SDIL groups. Following a similar pathway to the pass-through analysis, we will start with the graphical view before moving onto the structural break model as defined in equations 2 and 3. Figures 3.4 and 3.5 provide an overview of both the volume split and calorie contribution of our 4 SDIL categories.

Figure 3.4 Volume trends for each of the 4 SDIL categories

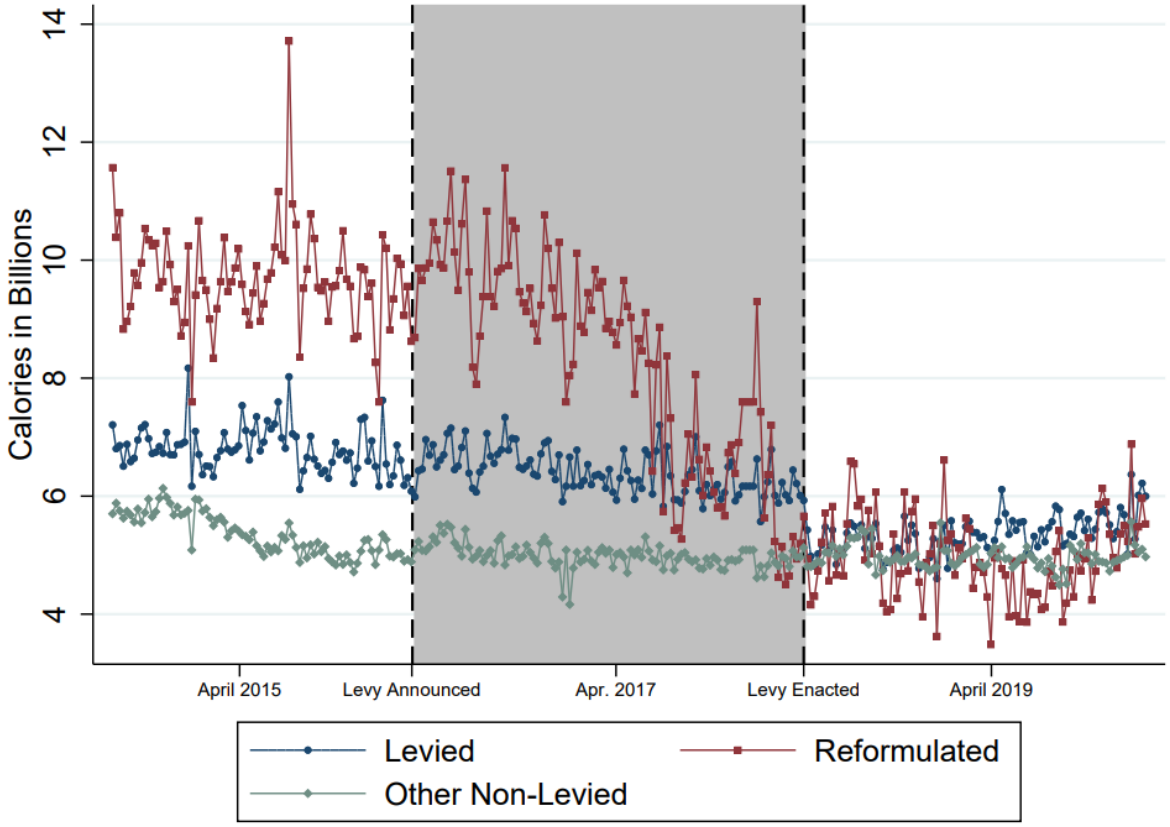


Notes: This figure shows the weekly sales volumes (in millions of litres) for four categories of beverages: levied soft drinks; brands which reformulated; diet and no sugar products which are not subject to the levy; and levy-exempt products (see chapter 2.9 for full definitions).

Other non-levied (which is shown by the teal diamonds), includes all the brands that as of March 2016 were exempt from the levy but were not actively positioned as diet alternatives. The graph highlights how significant the volume scale is in this category, representing circa half of all soft drink consumption, yet as shown in Figure 3.5 the calorie contribution is negligible. The basis for this is the volume of sales in plain bottled water (clearly no calories), and the significant volume represented by squash (very low sugar). Neither Figures 3.4 or 3.5

suggest a volume or calorie response to the SDIL implementation from the non-levied category, although the 'scorching' summer of 2018 and its impact on water sales can be easily identified.

Figure 3.5 Calorie trends for levied, reformulated and other non-levied categories



Notes: This figure shows the weekly calorie consumption from soft drinks (in billions) for three categories of beverages: levied soft drinks, brands which reformulated, and levy-exempt products. The time series for diet/zero-sugar beverages is not shown because by definition these drinks contain barely any calories (see Chapter 2.9 for full definitions).

Reformulated products (the red squares in both figures) remain relatively constant at the volume level, but as detailed in the previous chapter the calories drop significantly (effectively halving) during the grey shaded area - post announcement through to SDIL implementation – as a result of reformulation to avoid the SDIL.

Diet products can be split into two groups, namely those that contain less than 1 calorie per 100ml (such as Pepsi Max) and those that are have no added sugar, but do contain between 3% - 12% juice and therefore have some naturally occurring sugar and calories (such as Fanta Zero Orange which at 4% juice contains some 3 calories per 100ml). The steady increase through the pre-levy and shaded period is consistent with the previously shared narrative about change in consumer preferences. As Figure 3.4 shows this adoption trend seems to accelerate

following the levy implementation date and certainly does not seem to be impacted by the 8p -10ppl retail price increase we observed. The diet grouping is not shown on Figure 3.5 as it is effectively a flat line along the x axis – the additional volume growth effectively (if not quite) being calorie free.

Of most interest is the levied category (the blue circles) which pre the implementation accounted for circa 1 in every 6 litres drunk – but closer to 1 in every 3 calories consumed from soft drinks. The sales lines show a structural step down in both weekly volume (about 3 million litres) and calories (about 1.2bn a week) at the point of implementation. This impact is largely confirmed by the level-shift analysis in Panels B and C of Table 3.2. The first two columns show that as a result of the implementation of the SDIL, the volume of levied products dropped by about 20% which results in a largely mechanical drop in calories. Columns 5 and 6 indicate that diet drinks were the main beneficiary with a 6% – 7% increase in volumes.

Such switching is to be expected, as noted previously the majority of diet drinks, particularly in cola, are variants under the same parent brand and are therefore seen as close substitutes. Household panel data from the time of SDIL announcement showed that amongst UK households who bought multipacks of either regular Coca Cola or Diet Coke or both, some 39% of the total spend came from households who purchased both packs (Kantar 2015). Column 7 and 8 suggest there may also have been some substitutional switching into brands in the levy exempt category with a modest 4.2% increase in volume, and associated low level 0.2bn calorie increase.

3.10 Priced Marked Pack Response from Producers

In the first chapter we described the importance of PMP's within the 34,000 symbol and independent stores in the UK and how they uniquely offer producers the opportunity to set very visible retail price point. The extensive use of PMP's in soft drinks creates the opportunity to bring together the price point ending concepts from the first chapter with the SDIL analysis on leviable drinks presented in this chapter.

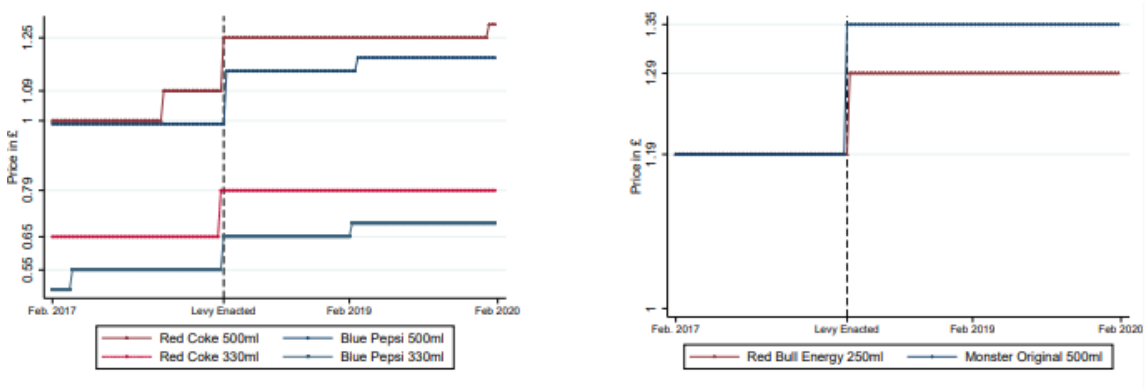
In this scenario, as the producer of a leviable drink heads towards implementation date they have a known COGs increase, VAT rate and existing customer fixed % margin. They need to decide whether they pass on the levy, and if so what specific price points do they choose.

The full pass-through rates (+ VAT) are:

250ml = 7.2p **330ml = 9.6p** **500ml = 14.4p**

and as the packs are in the public domain we can easily track PMP changes in Figure 3.6.

Figure 3.6: PMP price point tracking on drink-now leviable cola and energy



Notes: This figure tracks the introduction of new PMP's for the four levied brands across the SDIL implementation timeframe. The nature of these packs means this pricing information is in the public domain and hence this data is based on instore observation and not the Circana EPOS data which carries a specific pack usage restriction.

Not surprisingly, all leviable packs increase their PMP levels at the time of the levy implementation to cover the immediate COG increases:

Red Coke 330ml Can	*full pass-through = 9.6p*	*actual =14p*	**Index 146**
Blue Pepsi 330ml Can	*full pass-through = 9.6p*	*actual =10p*	**Index 104**
Red Coke 500ml Bottle	*full pass-through = 14.4p*	*actual =16p*	**Index 111**
Blue Pepsi 500ml Bottle	*full pass-through = 14.4p*	*actual =15p*	**Index 104**
Red Bull 250ml	*full pass-through = 7.2p*	*actual =10p*	**Index 139**
Monster Energy 500ml	*full pass-through = 14.4p*	*actual =16p*	**Index 111**

All the new price points chosen by producers are consistent with the maintenance of either 5 or 9 price endings and all round up rather than down!

The PMP analysis also provides a further example of the container / brand mix effect. Prior to the implementation a 250ml can of Red Bull and a 500ml can of Monster Energy carried the same PMP. Both then pass-through the levy (which for Monster in a 500ml can is double the Red Bull level) and price at the nearest 9 or 5. The effect of the levy pass-through splits the

pricing on the two packs with Red Bull no longer at parity, but now at a lower PMP can price than Monster. If this is sufficient to encourage some switching from Monster to Red Bull, this will mechanically drive further increases in the average ppl in the leviable energy category.

3.11 Aggregate SDIL Calorie Reductions from Reformulation and Pricing

The overall effect of the levy on total calorie consumption is a combination of the reformulation impact in chapter 2 and the pricing impact in this chapter. The reformulation impact from the IW adjusted specification was some 5.1bn calories per week by the end of the sample period in Jan 2020. The demand response (the higher price of levied cola) cut a further 1.2bn calories per week, although there was an offsetting increase of some 0.2bn calories moved in levy-exempt brands. Hence, the net effect is around 6.1bn calories per week with the supply side reformulation response accounting for around 84% and the remaining 16% accounted for by the response to levy induced increased pricing.

These findings are separate to the longer-term sugar reduction trends in the category and are based on a comparison with a pure no SDIL counterfactual. As the data shows, the overall reduction in weekly calories from the start to the end of the data sample was a fall from 23bn to 15bn calories per week. The analysis therefore suggests that some three quarters of the overall reduction in soft drink calories over this period can be ascribed to the SDIL - a policy intervention which provided the financial incentive (in some cases imperative) and then acted as a clear co-ordinating catalyst for the industry.

3.12 Pass-through on Future SDIL Rate Increases

This study has shown that behind the 50p (near doubling) headline rate for pass-through in the levied category, the exact way the SDIL influences ppl retail pricing is both complex and heavily nuanced. Allowing for the various mix effects the analysis calculates 30% – 40% over-shifting on levied cola whilst the pass-through on levied energy drinks is very close to the 28.8p straight pass-through hypothesis.

It is important policy makers understand the nature of this complexity, specifically the relationship and ‘balance of power’ between producers (brand strength) and their customers (retail strength) in any given market.

The UK's SDIL bands and tax levels remained unchanged from April 2018 through to April 2025, despite significant cost price and retail price inflation over these 7 years. For perspective, from 2018 through to 2024 the average retail ppl in UK soft drinks increased by some 41% (Circana 2024). Therefore, it was not perhaps surprising when the new UK Government (Labour - July 2024) announced a SDIL review in their first budget (October 2024) setting out a plan to both link the SDIL to RPI going forward, *and to catch-up with previous inflationary pressures*. This is shown in Figure 3.7.

Figure 3.7 HMRC Soft Drink Industry Levy Uprating Guidance (Oct 2024)

General description of the measure

As announced at Autumn Budget 2024, to protect its real terms value, both the lower and higher rates of the Soft Drinks Industry Levy will increase each year over the next 5 years to reflect the 27% Consumer Price Index increase between 2018 and 2024 as well as increase in line with the Consumer Price Index each year from 1 April 2025.

The rates will be adjusted to apply per 10 litres so that rate changes can be made in smaller increments, to reflect the Consumer Price Index more precisely. To illustrate using the existing rate, 18p per 1 litre becomes £1.80 per 10 litres.

The annual increase will be the total of:

- a 27% increase to reflect the change in Consumer Price Index from April 2018 to April 2024, spread equally over the 5 year period from 2025 to 2029 (this equates to a 10 and 13 pence per 10 litres increase per year to the lower and higher rates respectively)
- Consumer Price Index inflation over the previous year starting from April 2025 (This will be based on the Office for Budget Responsibility forecast for annual Consumer Price Index inflation for quarter 2 (1 April to 30 June) of the relevant year)

Rates will be increased on 1 April each year — the new rate, reflecting both the above inputs, will be announced in the preceding autumn fiscal event

Notes: HMRC guidance following the budget announcement in October 2024 – Source GOV.UK

Subsequently the new rates from April 2025 were announced as £2.59 per 10 litres at the higher tier and £1.94 per 10 litres at the mid-tier rate equating to a 7.9% and 7.8% increase respectively. Including VAT this would translate to a straight pass-through increase of 2.3p and 1.7p per litre at a retail pricing level.

Based on the 2018 experience, it would be logical for researchers to expect a straight pass-through of these increases with perhaps some over-shifting reflecting other confounding cost increases. Thinking as a practitioner, a different hypothesis is put forward, namely that in

contrast to the 2018 analysis, *there will be a very significant over-shifting of these SDIL increases as reflected in retail pricing*.

Why would this be the case? The original 24 ppl levy introduction was unprecedented in both its construct and scale, and seen by the industry as such. Hence whilst VAT was added and there was some over-shifting on levied cola, the retail price points that the levied brands moved to were consistent with a fall in % margins at both a producer and retailer level (as shown in Figure 2.13).

In an environment where there is an annual SDIL increase, both producers and retailers will consider the levy increase as 'business as usual' or simply as one of many cost pressures which need to be factored in to an annual cost price increase as part of the budgeting process. The result of this approach is that the SDIL is likely to be passed through on a % margin maintenance basis, *and this will drive significant over-shifting of the additional SDIL*.

We can use our 2L Fizzy Pop example to demonstrate this in Figure 3.8. As highlighted, the first annual SDIL increase, which came into effect in April 2025, was 1.9p per litre and hence some 3.8p on a 2L bottle. If we assume 50% gross margin (GM) at the producer and 40% profit on return (POR) margin at the retailer, the increase in retail price based on % margin maintenance is far more significant.

Figure 3.8 Straight levy pass-through : comparison with % margin maintenance

2L Regular Bottle Example	**Straight pass-through**	**% Margin maintenance pass-through**
Producer (50% Gross Profit)	3.8p	7.6p
Retailer (40% Profit on Return)	0.0p	4.9p
VAT (at 20% standard rate)	0.8p	1.3p
TOTAL	**4.6p**	**13.8p**

Notes: This shows the expected straight pass-through of the levy at 4.6p (where producers and retailers hold their cash profit constant but see a margin % fall) compared to the pass-through where they hold % margins (assumed in this example to be 50% GM and 40% POR respectively).

When producers and retailers protect their % margins the demand side impact of the new SDIL is some **3 x greater** than the straight pass-through. Such a finding is likely to be presented as significant over-shifting in future research studies, yet it is arguably the natural outcome of any policy which sees the SDIL increase by smaller incremental amounts on an annual basis.

There is evidence from the latest EPOS data (Circana 2025) of this impact already being seen in the market post the April 2025 SDIL increase as shown in Figure 3.9.

Figure 3.9 Average retail price per litre : 6 months post SDIL uprating increase

	Ave Retail £PL Apr - Oct 24	Ave Retail £PL Apr - Oct 25	Increase	Delta
Leviable Energy	3.97	4.27	0.30	**0.19**
Non-leviable Energy	3.69	3.79	0.11	
Leviable Cola	2.12	2.18	0.06	**0.04**
Non-leviable Cola	1.35	1.37	0.02	

Notes: Source is Circana EPOS 2025. The 1.9p (high-tier) and 1.4p (mid-tier) increases in the SDIL came into effect from April 2025. This compares the EPOS recorded retail price changes six months post the introduction with the same 6 month period in the previous calendar year. The data is split two ways, firstly into Energy and Cola and then secondly into levied and non-levied brands.

Figure 3.9 shows the scale of the increase in retail pricing split into four groups - leviable and non-leviable, energy and cola. This is shown through a straight comparison of two six-month periods, the first post the SDIL increase in April 2025 and the second, the same six-month period in the previous calendar year.

The scale of the increase is significantly higher than just the SDIL and also present on non-levied categories, however, this is not to be unexpected as it will reflect many other cost factors such as the changes in Employer National Insurance contributions which were also introduced in April 2025 (October 2024 budget - gov.uk)

However, the delta between the increases in levied and the non-levied equivalents is very interesting. Logically, the only difference in the COGs between these two groups would be the changes in the SDIL or the price of sugar and sweeteners, as all the other cost changes such as production, packaging and transport would be *consistent across the variants*.

Sweeteners are a relatively low-cost ingredient with relatively stable year on year pricing, whilst global sugar pricing actually softened marginally between 2024 and 2025 (Macrotrends 2025). The only key difference that should be expected between the prices of the levied and non-levied groups is the SDIL increase. A straight pass-through (including VAT) would have been 2.3p per litre, *the actual delta between levied and non-levied was 19p per litre on Energy and 4p per litre on Cola.*

This is very early descriptive analysis but the results are consistent with producers and retailers adopting a % margin maintenance approach. The logical rationale for why the delta between levied and non-levied for Energy, is greater than Cola, is because both the retail pricing per litre, and the % margins derived from the sales of Energy drinks are higher. (Forbes - Money 2014).

The policy implications of this type of % margin maintenance pass-through continuing on a year on year basis, *are very significant*. Such a practice would drive the retail price delta between the levied brands and their non-levied variants to a far greater level than policy makers potentially intended. For example, the compound effect of continuing with an annual 7.9% increase for the next 5 years (as per the stated UK government policy of keeping progress with current inflation *whilst* also recovering 27% of previous lost inflation) would see the highest tier of the UK SDIL reach 37.9p, some 13.9p greater than the 24p at implementation by 2030. This is shown in Figure 3.10.

However, if each of these increases is passed through by the industry on a % margin maintenance basis – and we assume 50% gross profit for the producer and 40% profit on return for the retailer, then by 2030 the effective rate of the SDIL higher tier on a retail pence per litre basis would be 84.2p (Figure 3.7). If in the energy drinks category, the margins are higher than those quoted above, for example 70% gross profit at the producer and then 60% POR at the retailer by 2030 the higher tier retail price impact would be 167.5p per litre (Figure 3.10).

Figure 3.10 SDIL difference between a straight vs % margin maintained pass-through

Year	2018 - 2025	2025	2026	2027	2028	2029	2030
SDIL Higher Rate (p)	24	25.9	27.9	30.1	32.5	35.1	37.9
Straight Pass Through + VAT (p)	28.8	31.1	33.5	36.2	39.0	42.1	45.4
50% Producer GP + 40% Retailer POR (p)	N/A	36.4	44.6	53.4	62.9	73.2	84.3
70% Producer GP + 60% Retailer POR (p)	N/A	47.8	68.2	90.3	114.1	139.8	167.5

Notes: This table represents the progression of the pass-through level to retail pricing that is required to hold cash profit level, compared to % margin maintenance at two different retailer and producer margin % levels.

If this is a potential unintended consequence, does it matter? As this analysis has shown energy drinks proved to be highly inelastic to the straight pass-through of the levy in 2018 and given their global reach, the functional role of sugar in the drinks, and the broad availability of diet variants, then arguably reformulation of the two main duopolistic brands would seem unlikely. Going forward, % margin maintenance pass-through will result in both the cost and retail price delta between the high sugar versions and the sugar free variants increasing (we have already

seen in Figure 3.10 that in 2025 leviable energy increased by 30p a litre, some 3 x greater than non-leviable energy which increased by 11p a litre).

The potential paradox or risk for policy makers is that the SDIL inflationary plus increases, applied on a % margin maintenance basis - *but only to regular energy,* will also drive the cash profit delta per can between the leviable and non-leviable variants *to the extent that it will encourage producers and retailers to want to sell more leviable energy over diet energy* – resulting in more support (advertising, sampling, retail space and presence) to drive sales.

This is shown in Figure 3.11 which contains *hypothetical* costs for the production of two 250ml energy cans, one full sugar and therefore leviable (in red), the other diet and therefore non-leviable (in green). The example flows through three stages pre-SDIL, SDIL implementation and 2030 post six years of annual inflationary plus increases. All other costs are held constant to allow easy identification of the SDIL pass-through impact. The first stage shows a set of COGs and costs with 70% gross profit (producer) and 60% retailer POR resulting in a retail price point of £1.79. The producer makes slightly more cash profit on diet (hypothetical sugar costs removed from COGs) whilst the retailer makes the same 89p cash profit on both variants at 60% POR.

The second section (2. SDIL Implementation) in Figure 3.11 shows the SDIL implementation with a straight pass-through – the exact scenario we saw in our analysis of drink-now energy. The straight pass-through of the 6p SDIL + VAT on 250ml of liquid causes the % margins to fall for the producer and retailer.

The hypothesis, that outside of the initial 2018 pricing SDIL shock and with consistent annual SDIL inflationary plus increases, producers and retailers will look to hold margins, leads to the third section (3. 2030 SDIL Inflationary Plus scenario). With % margins held, albeit at lower levels than pre the SDIL, the consumer is now paying 40p more for a 250ml can of full sugar vs diet energy.

However, what is really important is the cash profit delivery per can sold, which for both the producer and the retailer is now significantly higher for the leviable cans than the non-leviable cans. Specifically, leviable 250ml energy generates some 18p (or 30%) higher profit for the producer and 16p (or 18%) higher profit for the retailer than the equivalent non-leviable 250ml energy variant.

Figure 3.11 250ml Energy – SDIL pass-through examples (Red Leviable – Green Non)

1. Pre - SDIL (p)			
COGS Leviable 250ml Can	18	17	COGS Non-Leviable 250ml Can
Producer Sell Price	60	60	Producer Sell Price
Cash Profit	42	43	Cash Profit
Gross Margin %	70%	72%	Gross Margin %
Retail Sell Price	179	179	Retail Sell Price
Less VAT	149	149	Less VAT
Cash profit	89	89	Cash profit
POR Margin %	60%	60%	POR Margin %
2. SDIL Implementation (p) April 2018			
COGS Leviable 250ml Can	18	17	COGS Non-Leviable 250ml Can
SDIL	6		SDIL
Producer Sell Price	66	60	Producer Sell Price
Cash Profit	42	43	Cash Profit
Gross Margin %	64%	72%	Gross Margin %
Retail Sell Price	186	179	Retail Sell Price
Less VAT	155	149	Less VAT
Cash profit	89	89	Cash profit
POR Margin %	57%	60%	POR Margin %
3. 2030 Scenario - SDIL Inflation Plus			
COGS Leviable 250ml Can	18	17	COGS Non-Leviable 250ml Can
Initial SDIL	6		Initial SDIL
New Inflation SDIL	4		New Inflation SDIL
Margin % on New SDIL	8		Margin % on New SDIL
Producer Sell Price	78	60	Producer Sell Price
Cash Profit	50	43	Cash Profit
Gross Margin %	64%	72%	Gross Margin %
Retail Sell Price	219	179	Retail Sell Price
Less VAT	183	149	Less VAT
Cash profit	105	89	Cash profit
POR Margin %	57%	60%	POR Margin %

Notes: This is a hypothetical set of costings for two different 250ml cans of energy drink where red = leviable and green = non-leviable. The figure shows the flow through of costings from pre-SDIL to implementation to 2030 post six years of circa 8% annual increases in the SDIL. It shows how in an elastic market the % margin maintenance effect could drive producers and retailers to put more (rather than less) support behind the leviable variants.

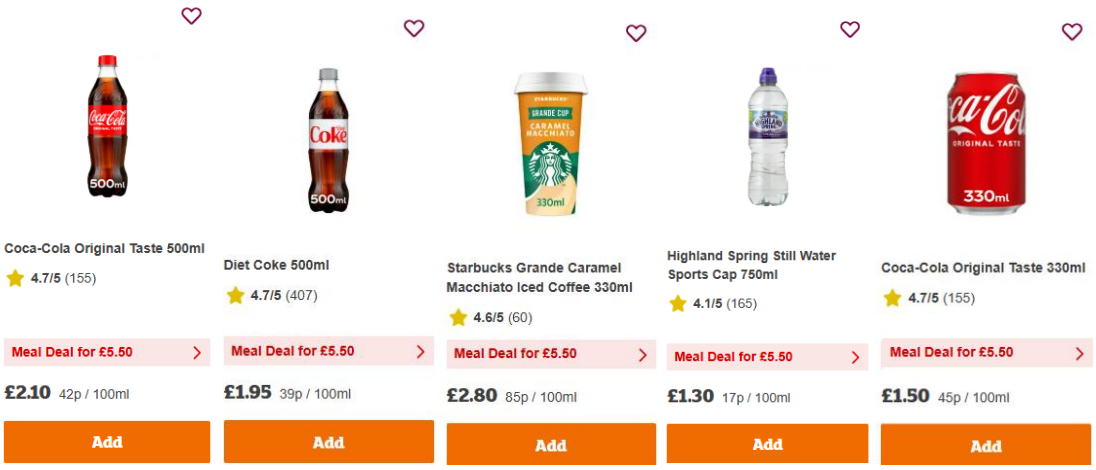
Would the 40p per can delta not encourage more drinkers out of regular and into sugar-free energy? If the consumer considers 'sugar-free energy' as something of an oxymoron and the sugar content as integral to the product proposition then the answer will be no. The demand side impact of the policy is ineffective, yet the supply (and retailer) side incentive has arguably 'gone the wrong way' as it is now to try and sell more full sugar than diet cans.

There is one further way in which the higher retail pricing on leviable items (driven by the SDIL and % margin maintenance pass-through) could in practice be counter-productive from a sugar reduction perspective. A key offering for many grocery retailers is the 'meal deal' where a main (normally a sandwich) a snack (normally crisps) and a soft drink are bundled into a single 'meal deal' price as shown in Figure 3.12. This figure, taken from Sainsbury's on-line store, shows an example of the meal deal concept where the retail price of Coca-Cola regular

500ml is £2.10 and the Coca Cola Zero (no added sugar variant) is sold at £1.95. Yet the meal deal price is £5.50 regardless of which drink is chosen (Sainsbury's on-line store Oct 2025).

The 15p delta in the retail pricing, which arguably reflects the SDIL pass-through of 500ml of leviable liquid is negated.

Figure 3.12 Sainsbury's meal deal - £5.50 regardless of which drink is chosen



Notes: This figure is taken from Sainbsury's on-line store in October 2025. It shows the two different price points for Regular Coca-Cola 500ml (leviable) and Diet Coke 500ml (non-leviable) but that the meal deal bundle price is consistent at £5.50. The same principle applies to the other 3 drink choices shown.

Furthermore, loyalty card analysis of shoppers' participation in the meal deal promotion (AG Barr / Tesco Clubcard analysis 2023) revealed two key insights. Firstly, on some drink-now products, meal deal participation accounted for the majority (>50%) of the unit sales of those items, and secondly, there is a clear behavioural tendency amongst shoppers, which can be seen through their combination choices, *to try and generate the highest savings possible through the meal deal promotion.*

For example, in Figure 3.12 the Starbucks Iced Coffee at £2.80 could be considered a more desirable purchase as part of a meal deal than the Highland Spring water at £1.30 simply on the basis as it generates an extra £1.50 of 'saving'. If as expected, 75%+ milk-based drinks (which are currently exempt) are included in the scope of the SDIL, then the likely outcome is an increase in the single unit retail price of this drink. This increase should, from a policy-makers perspective, either dampen demand or encourage reformulation. However, with the majority of iced coffee sales being as part of a meal deal, the retail price increase will not only be negated, the additional 'saving' offered could make it an even more attractive purchase to

the ‘savvy’ shopper looking to maximise their meal deal discount. This decision could also maximise calorie intake with Starbucks Iced Coffee containing some 200 calories per serve compared to Highland Spring water at zero calories.

If you consider the final product shown in Figure 3.12, a 330ml can of Regular Coca Cola at £1.50, there is an obvious question about the incentive for a shopper to purchase this reduced portion size (and save 71 calories) as part of their lunch, when the 500ml bottle equivalent is also part of the £5.50 meal deal as well?

Time will tell if these announced SDIL inflation plus increases are passed on by producers to retailers, and then retailers to shoppers, on a straight pass-through or on a margin % maintained basis over the next 6 years. As the examples above show, there could be a significant difference between the SDIL policy evolution *in theory* and the actual policy development *in practice*. Regulators need to be wary of unintended outcomes and consequences whilst the hypothesis provides an interesting basis for future SDIL and broader ‘sin tax’ pass-through research.

3.13 Limitations and Robustness

Whilst the EPOS data used in the study is of the highest quality and provides the best available read of the UK Soft Drink market, the first limitation in this analysis is that it measures the impact of the SDIL on the grocery market, or shop bought drinks, and not those drinks purchased from hospitality or food on the go outlets. However, we do know from nutritional labelling checks across 2017 and 2018 that all the staggered reformulations that took place were consistent across the various channels. This is to be expected, it would be highly unusual for brand owners to countenance any brand being sold in the same get-up but with channel dependent formulations. Hence the reformulation impact, which accounts for over 80% of the calorie reduction, will at least be consistent regardless of where the soft drink is sold.

A further data limitation is that whilst the percentage of the grocery market covered by this data is very high (80% – 90%), it does exclude some of the discount[52] and more premium specialist stores. The next section will provide a methodology to include them in a total market SDIL view.

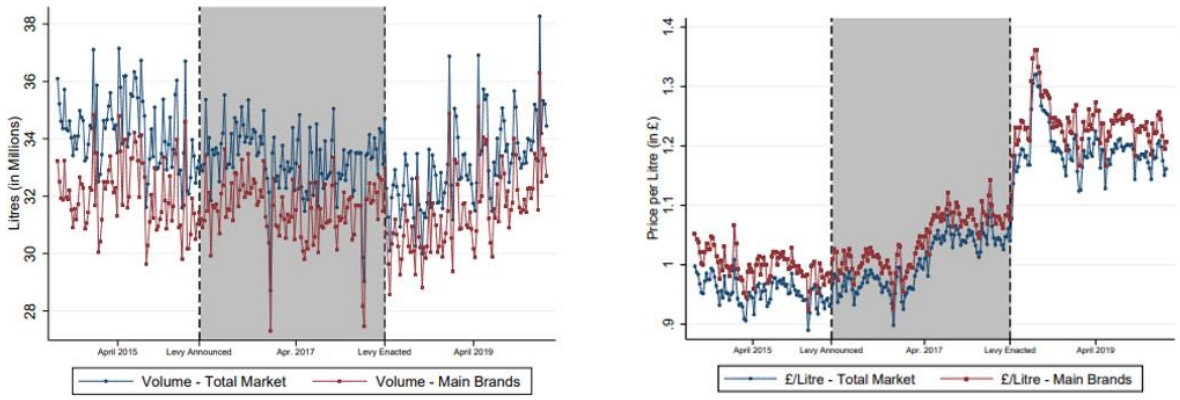
[52] The good news for further EPOS based studies is that these discount stores have recently announced they will share data going forward which will take the data coverage up to near 100% of all grocery outlets in the UK.

In terms of robustness of the analysis, the first question is the representativeness of our main sample consisting of the 100 leading brands and brand-variants. Table 2.1 showed that these brands account for about 73% of consumer spending on soft drinks in the data. The remaining 27% is mainly made up of store own brands.

There could be a risk that the price increase on leviable brands or the impact of the reformulation encourages consumers to switch into retailers' own brands and this impact is lost from the analysis. We can mitigate this risk in a number of ways. Firstly, it is notable that the retailers' own brands volumes do not seem to have been impacted by the SDIL implementation. The EPOS data splits out private label soft drinks at a category level and records post-levy aggregate volumes of 2.352bn litres for the year to end January 2020 which are remarkably similar to the pre-levy 2.374bn litres sold in the year to end January 2018 (Circana 2018–2020).

Secondly, if we look at the near duopoly market segments of cola and energy where we saw some over-shifting and full pass-through of the levy respectively, the analysis shows no deviation across the full market, nor in the share of the market captured by these main brands around the time the levy was implemented. This is shown for each of the segments (cola and energy) in Figures 3.13 and 3.14 respectively.

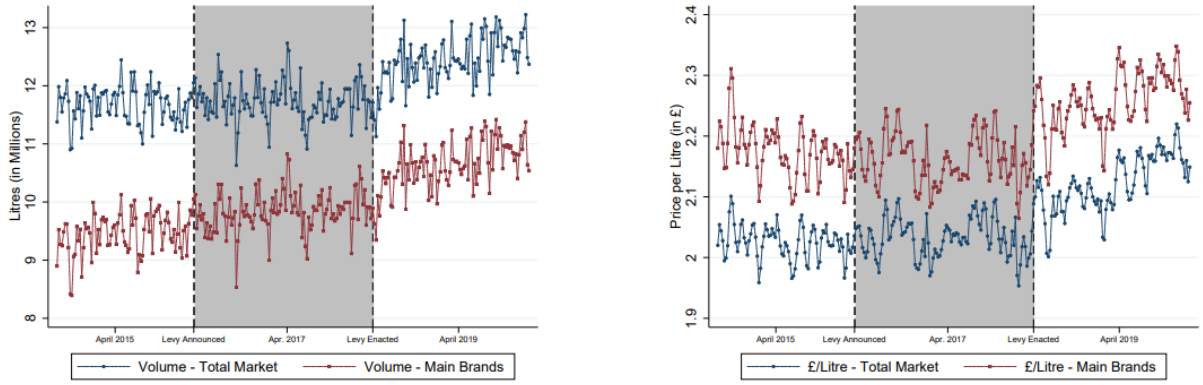
Figure 3.13 Cola : Top 100 Brands Comparison vs Total Market



(a) Volume **(b) Price**

Notes: Figure (a) compares weekly sales volume of cola drink brands within our sample of 100 leading brands (red squares) with the total market sales in this segment as per the full EPOS read (blue circles). The vast majority of the difference is accounted for by own-label brands. Figure (b) shows the same comparison but for price (in £/litre)

Figure 3.14 Sports & Energy : Top 100 Brands Comparison vs Total Market



(a) Volume **(b) Price**

Notes: Figure (a) compares weekly sales volume of sports and energy drink brands within our sample of 100 leading brands (red squares) with the total market sales in this segment as per the full EPOS read (blue circles). The vast majority of the difference is accounted for by own-label brands. Figure (b) shows the same comparison but for price (in £/litre)

There is no evidence to support the suggestion that consumers traded down from branded cola and energy into private label alternatives in response to the SDIL.

The representativeness of the data at both a full market and segment level is further supported by the figures in Appendix A1-8. These show how the market or segment made up by the main brands used in the study (red squares), and all brands (blue squares), follow virtually identical seasonal patterns in both sales volumes and retail pricing. There is also no sharp break in sales volumes at the point of levy implementation in any of the soft drink segments. For example, the leading fruit juice brands (Tropicana and Innocent) only account for about a third of the overall volume of fruit juice sold with the majority of the rest of the segment sales being in private label. Hence there could be an argument that if the increase in price of leviable cola and energy, or any consumer reaction to the reformulation of leading brands resulted in switching into fruit juice, we may not be able to fully capture this substitution in our main data set and analysis. However, as the appendix shows there was no volume or pricing reaction within this segment to either the announcement or implementation of the levy. The same holds true for water, another levy exempt category. In short, the top 100 brands can be taken as being highly representative of the overall market and it is highly unlikely that any cross-category movements are missed.

A common robustness approach in the literature is to choose a suitable control group and to re-run the pricing and volume analysis using a DiD methodology, (Taylor, et al., 2019), (Beradi,

et al., 2016) (Etile, et al., 2018), (Goncalves & Dos Santos, 2020) amongst others. The advantage of this approach is that in contrast to the interrupted time series, it allows for a full set of week fixed-effects and hence can better account for events that impact the overall soft drinks market. The water category seems like an obvious candidate for the control group and to fulfil this role it needs to meet two identifying assumptions. The first is that the cross-price elasticity between water and each of the levied categories (Cola and Energy) is close to zero, or put another way a change in price of full sugar cola or energy will have very limited impact on sales of bottled water. There are a number of logical factors that underscore this assumption. Firstly, the core cola and energy drink consumer needs of taste and function are simply not met by water and hence it would be an unusual close competitor. Secondly, the water category is also sold within its own category in a different part of the soft drinks fixture and at a much lower price per litre. Arguably, the main competitor for bottled water is the quality and availability of mains tap or on the go water fountains rather than other soft drink categories.

The second assumption, that water and the levied products are assumed to follow the same outcome time trends prior to the levy and would then continue to do so in the absence of the levy being implemented, is harder to support. The long-term changing consumer attitudes towards sugar evidenced in the previous chapter can be seen in Appendix Figure A9 which shows the slow decline in levied cola volumes and in contrast the long-term growth in water. This divergent trend is likely to account for the over-estimation shown in Appendix Table A2 where column (2) suggests that the levy led to drop in sales of levied products relative to water by about 25%, whereas the main results record an 18% reduction.

Soft drink practitioner experience would also flag an unusual confounding concern about the suitability of bottled water as a control group for carbonates. A graph plotting sales against mean temperature would show a similar demand curve for most categories across 95% of the temperature range, but there is a phenomenon during the hottest of heatwaves where consumers start to reject sugary carbonates and instead simply prioritise the importance of hydration, which is best delivered by plain water. Three of these ‘spike weeks’ when water arguably becomes the main substitute for SSBs can be clearly seen in Figure A9. They are often, however, followed by a confounding drop in volume, not necessarily because of a sharp reversal in temperature, but because the UK water supply chain, which is highly dependent on deliveries from France and Scotland, is simply unable to cope with the additional demand and significant gaps appear on shelf until supply stabilises.

3.14 Estimates to Calculate the SDIL Impact on Total UK Soft Drinks

Three data limitations were highlighted in the previous section. Firstly, the selection of the top 100 brands for analysis, secondly the lack of full discounter and specialist sales and finally the lack of market read for the hospitality sector. This section will show how estimates can be made for each of these areas to build on the 6.1bn SDIL calorie reduction impact that has already been presented in this study.

Starting with the use of the top 100 brands for the analysis. Whilst in levied and heavily reformulated categories the top 100 brands gives a high level of total market coverage (98% of £'s in cola, 81% in OFC's and 89% in sports and energy) there is clearly some consumer spend and volume sitting outside the top 100 grouping. The vast majority of this volume sits within retailers' own brand propositions, sometimes referred to as private or own label.

It is important to remember retailers are also brand owners, and even though they typically use third parties to produce on their behalf, they still face the same set of SDIL regulations (and hence costs and decisions) as branded producers.

The analysis challenge presented by own brand is the sheer number of individual lines (and hence EAN codes) which makes it largely untenable to accurately track nutritional information and any changes to formulations over time. Put simply, whilst a Fanta Orange 2L will have the same formulation in every store, each retailer and wholesalers' own brand 2L Orange will have a different formulation.

Therefore, to include own brand in the analysis we need to consider this volume at an aggregated level and apply some assumptions based on the policy statements made by individual retailers. By the implementation date of the levy Tesco, Asda and Morrisons had all (helpfully) made public statements confirming they had fully reformulated their entire own-label range to below the 5gram threshold. Sainsbury's, the other member of the 'big 4', also reported in their 2018 Annual Report that they had cut the sugar levels on their leviable own brand lines by an average of 39% and in so doing had largely avoided the costs of the SDIL.

This approach is not surprising, it has been highlighted earlier how a number of retailers themselves were at the vanguard of championing sugar reduction and given the soft drink 'own

brand' is the same 'brand' they present across all the other food products in the store there is a significant additional rationale to put forward a progressive healthy proposition.

There is also the financial rationale for reformulation. Own brand typically sells at a lower price than the branded equivalent and as we have seen, the volumetric nature of the SDIL would naturally narrow the % gap between the two products should both choose not to reformulate.

We have also seen the role the SDIL played in acting as a co-ordinating catalyst for producers (this level, by this date or this cost). This was not required for retailers in quite the same way; they would naturally gain an understanding of the intentions of the brand owners (arguably the main competition for their own brand propositions) through the ongoing discussions with their branded suppliers.

In terms of calculating the SDIL calorie reduction for own brand the following methodology can be applied. For each segment within soft drinks the EPOS data provides a regular vs diet volume split for own brand sales. For the dairy, lemonade, fruit juice and water segments of the market it is fair to assume no reformulation took place as they were either levy exempt or below the 5gram threshold to start with. For all the other segments an assumption is made that the own brand products originally contained the same amount of sugar as the branded equivalents and then reformulated to just below 5 grams to avoid the levy. This hypothesis was validated with nutritional label checks instore at the time of implementation and through this methodology we can estimate that own brand reformulation delivers a further 165m calories per week reduction.

The addition of own brand sales takes the coverage to 93.1% of the available EPOS data set. The remaining 6.9% is spread across some 2,000 individual brands. Whilst a simple extrapolation across these remaining brands would add a further 365m calorie reduction per week this approach is likely to be flawed for two reasons. The first is because of a provision within the SDIL legislation for small producers to claim exemption from the levy on all categories of soft drinks providing their volumes are less than 1m litres per year. The second is that a number of these smaller brands are likely to be 'craft' producers who are arguably less willing to substitute natural sugar for artificial sweeteners. To be conservative in estimating the total calorie reduction, it is assumed that none of these brands reformulated, thus ignoring any potential calorie reductions from these 2,000 brands.

It is also possible to estimate the calorie reduction within the rest of the market not covered by the grocery EPOS data. The first 'missing' sector is a combination of continental discounters,

value retailers and at the more premium end specialist retailers such as Marks and Spencer. The best data source to approximate sales in these retailers is household panel data which provides a good read of soft drink 'take-home' sales across the UK. Access to Kantar panel data was also provided by AG Barr and it showed aggregated sales of some 1.2bn litres per year as sold, which adjusts to 1.5bn litres per year once squash is adjusted to reflect the dilution factor. This adds circa 15% additional volume to the level in the EPOS data and applying the logical assumption that these stores sell the same product mix as the EPOS measured retailers, this generates a further 900m calories per week reduction through the SDIL.

The other missing elements of the soft drink market are hospitality which can be broken down into 'Foodservice' and 'Licensed' (also commonly referred to as the 'on-trade'). Foodservice covers contract catering in education and workplaces, fast food, leisure venues, events and travel, whilst Licensed (which is where alcohol can be sold or served alongside soft drinks) covers hotels, pubs and restaurants. Britvic plc, are a key supplier to both these channels and publish in the public domain an annual review of the overall soft drink sales in both Foodservice and Licensed outlets, including details of volumes sold by segment. The 2017 report records total annual channel sales of 1.1bn litres and 0.7bn litres in Foodservice and Licensed respectively (Britvic plc., 2018).

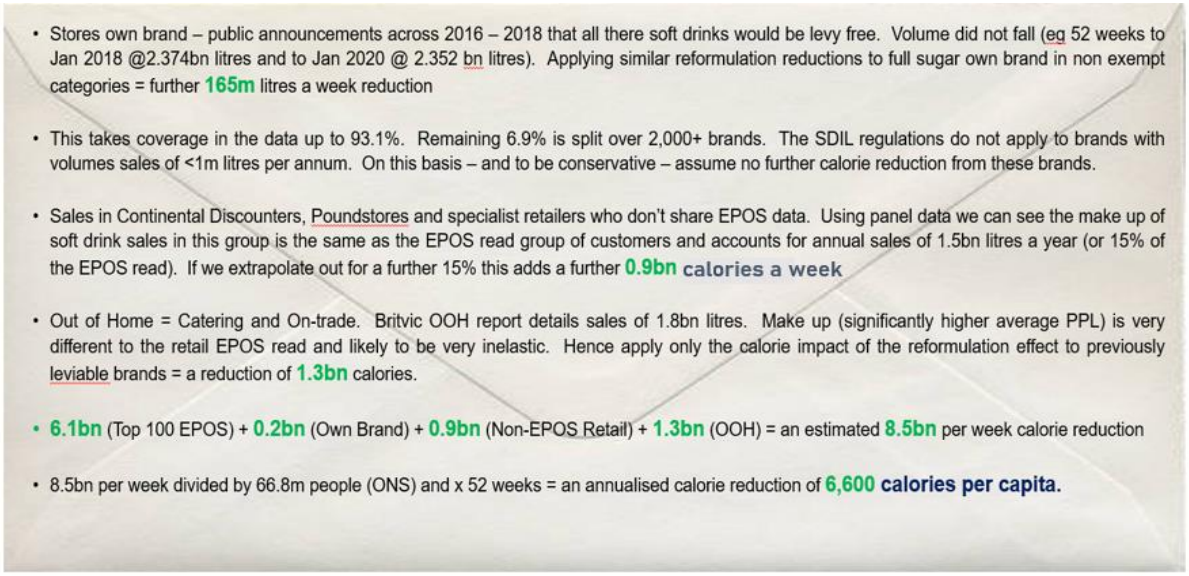
The split by category of sales in the on-trade is fundamentally different from the off-trade channel (grocery), and hence it would be flawed to simply extrapolate from the EPOS estimates. In particular, consumers in Foodservice and Licensed are likely to be less price sensitive and as shown in the soft drink market introduction the retail price is significantly higher (typically by a factor of 6) than in grocery and convenience. Therefore, any levy-induced price increases for levied beverages are much smaller in relative percentage terms. In order to err on the conservative side, it is assumed that any retail price increases are too small to prompt on-trade consumers to reduce their consumption of levied drinks. A consumer is unlikely to change a bar call for a double vodka (£6) and Red Bull (£2.50) at a combined £8.50 because a full pass-through of the SDIL has now made it £8.60. Therefore, the assumption in this channel is that all calorie reductions will come through product reformulation.

To calculate the total calorie reductions, the estimate focuses on three main reformulating segments which translates to a further 1.3bn calorie reduction per week.

Whilst this estimate may seem a bit 'back of the envelope' – it conservatively adds a further 2.4bn calories to the 6.1bn obtained via the analysis of the EPOS data taking the overall SDIL

impact to 8.5bn calories. Based on an ONS estimated 2019 population of 66.8m people, this translates to an annual reduction of 6,600 calories per capita as shown in Figure 3.13.

Figure 3.15: 'Back of the envelope' estimate of the total UK SDIL calorie reduction



Rogers et. al (2024), used the National Diet and Nutrition Survey (NDNS) and employed a controlled interrupted time series to isolate and determine the calorie reduction impact of the SDIL. The NDNS is a very different data source, using a small, but representative sample of the population to record what people actually eat and drink (rather what they purchase). The NDNS can also segment the data between adults and children.

The study identified an 'SDIL responsible reduction' in free sugar consumption from drinks of 5.2 grams per adult and 3.0 grams per child, per day. Multiplying this through to a weekly calorie reduction (based on 3.9 calories per gram) and applying the 2019 ONS population estimates generates a weekly calorie reduction figure from the SDIL of some *8.6bn calories*. A very different methodology, but also encouragingly consistent with the *8.5bn calories* estimated using the market extrapolation methodology.

It is important to note that the annual calorie reduction will be significantly higher than the average per capita (6,600 calories) amongst more frequent consumers of soft drinks, and particularly for those of the reformulated brands. For example, if we take a person who drinks a can of a reformulated brand (say IRN-BRU) every day with their lunch and dinner, and does not change this or any other consumption pattern then we see the following change in calorie consumption:

2017 = 730 Regular IRN-BRU cans x 138 calories per can = 100,740 calories

2018 = 730 Regular IRN-BRU cans x 65 calories per can = 47,450 calories

Reduction of 53,290 calories

What impact does a reduction of this level of calories have on weight loss and obesity? A study in the mid-20th century led to the popular concept that a weekly deficit of 3,500 calories equated to a 1lb of weight loss (Wishnofsky, 1958). Using this calculation under ceteris paribus conditions, the 53,290 annual calorie reduction would translate to this IRN-BRU drinker losing over a stone in weight (15.2lbs) across the first year of the SDIL.

More recent studies conclude that changes in the way the body responds to calorific deficit mean this heuristic is both an over-simplification and an over-estimation of actual weight loss (Egan & Collins, 2022), (Hall & Chow, 2013). However, in a meta-analysis of various diet plans Kim (2021) concludes that a sustained daily calorie reduction is the most important factor in the effectiveness of a diet achieving weight loss. Arguably, the reformulation of a regular drink, that is drunk regularly, where the drinker is unaware a reformulation has taken place, is the perfect example of a consistent change in daily calorie consumption.

3.15 Conclusion

This chapter uses high-quality EPOS data for a sample period of 288 weeks from July 2014 to January 2020, combined with longitudinal data on the nutritional content of the main soft drink brands to provide an analysis of the pass-through and demand side impact of the SDIL.

This complements the supply-side analysis in the previous chapter to show that the annual per capita calorie reduction of 6,600 calories, attributable to the SDIL policy, can be split circa 5,500 calories ($5/6^{th}$) from reformulation, with the remaining 1,100 calories ($1/6^{th}$) coming through the impact of the levy on retail pricing and hence consumer purchase decisions.

Whilst the headline finding of a pass-through of 50p per litre on the aggregated leviable brands reflects a near doubling of the 24p per litre initial tax rate, this chapter has further explained why this headline is an over simplification and potentially misleading for both researchers and policy makers. The analysis shows that leviable energy drinks delivered a near straight pass-through of the new tax, whilst there was some 40% over-shifting from leviable cola.

The way the actual pricing response manifests itself across the different categories, brands and pack sizes is both complex and heavily nuanced and a high degree of granular inquiry into market segmentation is required to truly understand the impact of the SDIL on consumer decision making behaviour.

The chapter also considers how the recent policy development of annual inflation plus increases in the SDIL rates may result in significantly higher levels of over-shifting going forward with the significant risk of some unintended consequences for policy makers.

The UK SDIL has undoubtedly been successful in achieving the government's aim of reducing the amount of sugar (and hence calories) from soft drinks. This is primarily due to supplier rather than consumer responses, a key insight for other policy makers considering this type of intervention in other regions or food categories. The recipe for an effective sugar tax would seem to be:

i) Ensure the tax is both tiered and substantial.
ii) Give brand owners the opportunity to avoid it completely.
iii) The avoidance requires challenging but technically feasible reformulation.
iv) Allow enough time for this reformulation to take place.
v) Act as a co-ordinating catalyst in terms of dates, levels and costs.
vi) Accept the more successful the structure, the lower the tax take will be.

Section 4:

[53]

Overall Thesis Conclusion – Looking Forward

4.1 'Pricing in the 9's'

Having kindly taken the time to read this thesis, I really hope that when you next walk into your local grocery store and face that 'moment of truth' when you choose a soft drink from the chiller, the purchase decision will be made with type 2 thinking and more consideration of both the price point and the sugar content!

If this store is one of the larger multiple chains in the UK, it is highly likely you will be seeing a price ending in a 0 or a 5 and highly unlikely the price will be ending with the number 9. As evidenced in the first chapter, this represents a significant disconnect between the profit maximisation recommendations made in academic studies of the left digit bias concept, and the pricing strategies currently deployed by the UK's largest grocery retailers.

Section 1.5 presents some logical reasons why this might be the case. There is of course also the possibility that, as per J.C. Penney a century ago, the pricing strategy in these 3 largest retailers has already been informed by a series of experiments, or the use of other econometric methods within the store portfolio or on-line shopping propositions.

UK grocery retailers are incredibly well placed to quickly and cost effectively run field experiments to test any given pricing hypothesis. A simple concept is that of the 'stores cluster' where individual stores can be placed into groups that are matched based on geography and demographics, such that a single treatment effect (for example different price endings) can be tested with near perfect 'ceteris paribus'. The same concept can also be applied to 'shopper clusters' using the unique insight which can be gained from store loyalty card data.

[53] Copyright Tesco Stores Plc

It seems inconceivable, given the financial impact of price endings, that profit maximising businesses of this scale would not have explored the relative sensitivities of different price-endings. However, if this is not the case, or the analysis has been limited, there is a strong argument for the recruitment of applied economists or a partnership with a suitable academic institution. There is a poignant, personal throwback in this recommendation to the study I originally undertook for P&G and the Co-op back in 1992.

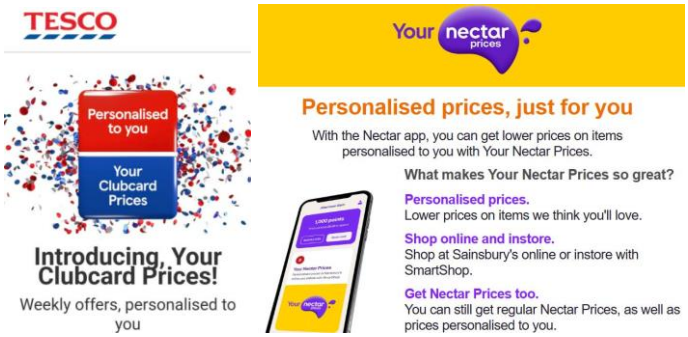
There is also arguably a link between price ending analysis and game theory within the various 'price match promises' made by retailers. These promises will both influence specific price endings whilst potentially acting as a (legal) co-ordination mechanism across retailers. It is significant that the three largest retailers run the same round pounds and quartile pricing strategies, with the exception of those SKUs chosen to be included in their discounter price match baskets as shown in the Warburtons bread example in Figure 1.3.

Brand owners in FMCG do not currently have access to the same quality of pricing and sales data generated by retailer loyalty cards, and as discussed in the introduction they do not have the control of retail pricing to run field experiments. The exception, exploited in chapter one is the use of PMP which naturally creates a stable pricing environment for academic enquiry but lacks the dynamism or flexibility to run experiments at pace. The good news for brand owners (and future academic research) is that new technology is once again acting as a disruptor. It is notable during Covid19 how many grocery brand owners moved quickly to introduce direct to consumer (D2C) purchase options through the establishment of their own on-line platforms or via hosted market places such as Amazon and Ebay. Many of these new routes to market have outlasted the end of the pandemic and they now provide new levers for brand owners to run fast paced pricing experiments or trials such as different coupon values being offered on a randomised basis to test demand sensitivity.

Through the long-standing relationships I have formed with various Executives at the major retailers across my career, I was able to ask a number of them to informally share their thoughts and perspectives on the future of grocery retail pricing and pricing strategies. One consistent word used across a number of discussions was 'personalisation'. Based on these conversations there is an expectation amongst retailers that that the technology led, pricing 'game-changer', will be the ability to execute *personalisation at scale*. Enhanced data analytics capability coupled with the increased usage of loyalty cards will increasingly give retailers (and to some degree brand owners) the ability to either create profit optimised, personalised price endings or

to make the actual shelf prices seen instore as largely irrelevant to the purchase decision. Figure 4.1 shows recent (2025) screenshots from Tesco and Sainsbury's websites. It is clear that pricing personalisation is already more than just a theoretical concept.

Figure 4.1 Tesco and Sainsbury's websites – loyalty card screenshots (2025)



Notes: Screenshots taken in Feb 2025 (Tesco) and July 2025 (Sainsbury's / Nectar). Re-produced with respective permissions.

This capability to personalise can be incredibly powerful for those who control the data and can quickly access and harness the insights. For example, personalised price endings could be introduced based on whether the individual shopper exhibits strong left digit bias or purchases more when presented with round pound simplicity. Perhaps in the future it could be of benefit to be a highly promiscuous shopper (one that regularly switches store fascia) on the basis data analytics will identify this trait and these shoppers will be targeted with the deepest offers, constructed specifically to try and increase loyalty.

It is still important to recognise that the quality of the targeting or personalisation will be linked to the quality of the data and the ability to turn this data into behavioural insight. Beyond a few generic 'field based' questions, such as number of dependents in the household or the main address of the cardholder, the retailer will need to form their segmentation based on what they see purchased when the loyalty card is presented. If the cardholder is highly loyal to a given retailer this will create a significantly better data stream than if they are a promiscuous in their shopping habits. For example, if a new family uses Tesco and its Clubcard for all their grocery shopping but makes all their baby category purchases in Boots any segmentation or personalised targeting strategy for that household is likely to be flawed.

For brand owners, outside of any D2C platforms, personalisation is likely to be based on the development of each pack being printed with its own unique quick response (QR) code. Linked to a brand loyalty app, this would develop a direct relationship between the brand owner and the individual purchaser, something which is currently only possible with D2C sales. This link

could be used to promote or price directly to the shopper, effectively redistributing the current level of final pricing control away from the retailer and more towards the brand owner.

The final comments in this section relate to the potential for future academic research based on access to both retailer EPOS data and loyalty card data. There are three main challenges with access to both data sources. Firstly, the data sources are heavily commercialised by a small number of global data providers. The majority of the data is purchased by brand owners who increasingly require the insights it provides to gain support from retailers for their brands. The second challenge is a conflict of interest where the data providers would rather sell the brand owners the analysis and insights than see this done by academic institutions at potentially better quality and lower cost. Finally, there is a commercial sensitivity to the data which arguably does not sit well with the concept of academic independence and public domain research. All these factors added together create an environment where the data providers are naturally concerned about retailers or brand owners sharing EPOS with academic institutions or directly granting lower cost / free academic access to this 'valuable' data. The pursuit of new public domain knowledge is always going to be tempered by the potential impact this may have on the business and operating models of data providers, retailers and bran owners.

Hence academic usage of both EPOS data and specifically loyalty card data is still very much in its infancy despite it being 30 years since Tesco launched Clubcard and the now almost ubiquitous presence of app-based schemes in most UK retailers. A programme such as Tesco Clubcard creates a rich data source which removes the statistical significance limitations and large store bias of household panels, albeit the lost spend in competitor stores remains a limitation. There is some evidence of usage development, for example the University of Nottingham establishment of an 'Environmental Food Purchasing Index' (University of Nottingham announcement, Oct 2024) or trial projects run by the Consumer Data Research Council (CDRC) in partnership with Sainsbury's Nectar card data (CDRC website 2025).

Looking forward, there is the 'nirvana' potential to track consumer purchase behaviour across aggregated loyalty schemes if solutions can be found to retailers concerns about both the commercial sensitivity and the commercial value of the data. There is undoubtedly the power within loyalty card data to either answer the question "a penny more or a penny less?" or through mass personalisation to effectively make it redundant.

4.2 UK SDIL

Whilst commercial tension will always exist in regards to FMCG data usage in academic research, there is no doubt that access to retailer EPOS and loyalty card data is easier to achieve if the research impact provides some 'common good' benefit. An example of this is the study of public health policy and interventions such as the UK SDIL.

The introduction and impact of the UK SDIL has now received significant academic enquiry, including a £1.55m funded research programme run by a study team of 22 notable academics based across 5 different UK institutions (NIHR award no. 16/130/01). The general sentiment from all the post implementation research echoes the findings of this study; the UK SDIL has been a highly successful policy intervention with clearly definable sugar reduction outcomes ahead of the policy objectives. Hence this final section considers three specific questions:

1) What additional insights can be found in the more recently published SDIL papers?
2) Can the insights in this study (and others) drive public health benefit on a global basis?
3) What insight does this study provide for the future of the SDIL / broader UK food strategy?

An interesting start point for question 1) is to consider a qualitative research study based on interviews with 14 senior grocery industry executives between 2018 and 2020, which presents the 'food and drink industry view' of the policy implementation (Jones, et al., 2023). The paper highlights 5 main themes, starting with 'why us?' or 'why make the intervention only in soft drinks when it was already making such good sugar reduction progress anyway'. The industry executives highlight the complexity in mass reformulation, and also call-out what is seen as a lack of level playing field, specifically in the exemption of added sugar milk shakes and coffee. Finally, the executives reference the concept that the 'consumer is king' and the crucial importance of the policy pushing on an existing set of changing consumer preferences. They then further reference how they believe the continuation of these trends coupled with the success of the SDIL is having a ripple effect across the wider food and drink industry (encouraging other categories outside of soft drinks to start the groundwork on reformulation).

From a quantitative and empirical perspective Luick et al. (2024) employ an interrupted time series analysis to present the impact of the SDIL on the soft drink market from 2017 – 2020. However, the study is limited by a lack of access to EPOS data which means the pricing and nutritional observations are unweighted. The base reference period is also set as six months

prior to levy implementation (Nov 2017–Apr 2018) by which time over half of the product reformulation had already taken place.

The most pertinent research question which naturally flows from the estimated 6,600 per capita reduction in annual calories in this study, is whether this reduction can be causally linked through to better health outcomes and specifically a reduction in obesity and improvement in dental health. This is tackled by Rogers et al. (2023) who use an interrupted time series and data from the National Child Measurement Programme to try and isolate an SDIL impact on childhood obesity. The results suggest that the SDIL was associated with a decrease in obesity in Year 6 girls, but not Year 6 boys, nor reception class aged children (the two age groups measured). Whilst these results are perhaps initially disheartening, it is arguable that a longer timeframe than 19 months post implementation will be needed to see the impact of the policy. A soft drinks practitioner might also suggest that analysing the impact on children aged 4 - 5 years and 10 - 11 years is always going to be limited by the 'gatekeeper' effect. In short, most children of these ages drink what they are given by adults and not what they would choose for themselves.

Practitioner research into soft-drink consumption levels across different age cohorts identifies that most SSB consumption starts in early teenage years, post the ages analysed in this paper. This is confirmed by the National Diet and Nutrition Survey (2019 – 2023) and a report produced by the UK Office for Health Improvement and Disparities (2025) which records daily consumption of SSBs increasing from 33mls (aged 1.5 to 3) to 54mls (aged 4 to 10) to 124mls (aged 11 – 18). There is a point in time, often linked to the start of senior school attendance, when the child starts to make their own soft drink choices. It is this point which is associated with the step-change in consumption and hence research would arguably be better focussed on teenagers.

Broadening the age range of study beyond young children, or finding another country as a control group which had similar obesity trends but didn't enact an SDIL policy, may result in a more robust and successful methodology to identify specific health benefits. Ireland, which has the closest grocery market comparison to the UK[54] would serve as an ideal control group, were it not for the fact they implemented their own similarly structured SDIL equivalent only 3 weeks after the UK. Australia remains a notable country where there are many similarities

[54] The majority of soft drink SKUs sold in the UK and Ireland (pre DRS in 2024) shared the same barcode with a number of retailers (such as Tesco) present in both countries.

to the UK grocery market and where dental health and obesity data is nationally reported (Australia Institute for Health and Welfare). There has been significant debate about the merit of policy intervention in Australia, however no legislation has yet been passed. This market could potentially provide a robust control group for the UK for a longer-term analysis of the impact of the SDIL on both obesity and dental health.

There is also the option to consider how regional variations within the UK could provide evidence of the causal link between SDIL and obesity reduction. For example, the decision by the popular Scottish brand IRN-BRU to reformulate created a higher % reduction in calories in this devolved nation compared to any other part of the UK (AGB 2019). A further key consideration of the UK SDIL relates to the consumer equity effects of a reformulation response compared to the demand side impact of a 'normal' sugar tax. As highlighted in 2.7 the addition of the SDIL to a 2L bottle of regular sugared carbonate (10 grams per 100ml) sold at a £1 would likely see the retail price increase to £1.58 based on a straight pass-through. If there was no option to reformulate to fully or partially avoid the SDIL, then on implementation consumers would be faced with three choices, i) paying the additional 58p = a 58% price increase, ii) switching to a 2L no added sugar variant or other non-leviable substitute to avoid the increase or iii) making no purchase.

The individual shopper response will depend on a number of factors. The most logical hypothesis is that the key determinant will be the relationship between the level of the price increase and the level of disposable income available to the consumer. We can see in the structural break analysis in chapter 3 that leviable volumes fell by some 20% in response to the higher pricing with a 7% and 4% increase in diet and non-leviable volumes respectively, keeping overall soft drink volumes consistent. What we don't know is the demographic profile of those who paid the higher levied price and those who switched. EPOS data simply can't provide this insight. It can, however, be found in panel data where the panel member has disclosed household income or within loyalty card data using address as a proxy for affluence. Fichera, et al., (2021) were able to access loyalty card data as the basis of their Catalonia study and hence were able to examine whether the shopper response was homogenous or heterogenous and the factors behind this. Interestingly, and contrary to the hypothesis above, the study found relatively larger reductions in the purchase of higher sugar Colas and OFC's amongst the relatively wealthier customers. The explanation put forward is that for these households, knowledge of the tax may be more salient and it is this factor which triggers a 'less healthy' understanding, something wealthier consumers are more likely to respond to.

This heterogenous response is a very interesting route for further UK SDIL research and would help inform whether the SDIL is a financially regressive tax on some consumers. The research might for example contradict the Catalonia findings and show that the amount of disposable income is the key variable in the shopper response. Alternatively, it may support a hypothesis that the physiological energy benefit of the sugar level means that those involved in heavy manual labour are much less likely to substitute to non-added sugar drinks than potentially higher paid office based employees. One of the key benefits of a mass reformulation is that it provides a consistent and health progressive response, removing the difficult question of whether the tax is regressive for lower household income drinkers.

Research to determine the relationship between the SDIL and better health outcomes is the obvious next step in providing a better understanding of this policy, and from a personal perspective there is a strong motivation to continue this work.

However, as shown in the review of the recent papers that look to causally link the UK SDIL to better health outcomes, this is very challenging to prove and caution must be exercised. The measurement of public health benefit is a dynamic and multi-faceted concept influenced by many factors which may confound any given identification strategy. Some of these confounding factors were set-out in chapter 2 with the word fortuitous used to describe the relatively clean period covered by the 288 weeks in this analysis. Post this period followed covid19, soft drink shortages, high retail price food and drink inflation, HFSS policy interventions and restrictions, energy drink age bans and some unusual 12 month phenomenon's such as the rise and subsequent fall in sales of the Instagram influencer backed Prime sports drink.

If robust analysis can be completed the link to better health outcomes would undoubtedly help inform or potentially strengthen the policy debate in those countries who have not yet implemented SDIL policies *or are considering the development of existing policies*.

Whilst the list of countries implementing soft drink 'sugar tax' policies has continued at pace, with some 18 new national and 7 new regional 'tax interventions' introduced from the start of 2019 through to the end of 2023, the awareness of the potential impact from supply side reformulation is arguably still limited. Despite the now evidenced success of threshold-based policy structures such as the UK SDIL and other countries such as South Africa, Portugal,

Spain and Ireland, it remains only circa 10% of the countries who have a soft drinks tax that use thresholds to encourage reformulation to partially or fully avoid the tax.

Perhaps the most interesting market for future policy intervention is the United States, the home of world's largest SSB brands where some 340 million people drink some 42 billion litres of carbonated drinks a year (Statista and Beverage Digest 2024). This is some 124 litres per capita, roughly double the level of per capita consumption seen in the UK.

The US also has a much higher share of its mainstream carbonates market in full sugar (>10gram per 100ml) variants compared to the UK. In 2024 full sugar accounted for some 73% of total mainstream carbonate sales (Beverage Digest 2024); whilst the equivalent in the UK was 21%. In short, the average US consumer drinks 7 times as much full sugar (>10 gram per 100ml) liquid as the average UK consumer.

Applying a simple US future target split of a 1/3rd of the mainstream carbonate volume in diet, a 1/3rd reformulated to 5grams per 100ml and a 1/3rd remaining at full sugar delivers a circa 4.2 *trillion* calorie reduction in the US. This equates to an annual reduction of some 12,000 calories per capita. *This potential transformational policy intervention has been proven in the UK and other countries, it simply needs the political will in the US to deliver it.*

The political will to tackle the obesity crisis in the UK through food and drink policy intervention remains strong, and it is expected that in the 2025 budget the Government will announce a series of changes to the UK SDIL. As previously highlighted a 5 year 'inflation-plus' set of SDIL ppl increases has already been confirmed with the first increase coming into effect in April 2025. As shown in chapter 3.12, the way these annual incremental increases could be passed onto the retailer by the producer, and then onto the shopper by the retailer, may result in significant over-shifting and some unintended consequences for policy makers. Specifically, this over-shifting would result in much higher levels of cash profit per unit sold from regular variants, which is likely to encourage additional support for leviable brands from both producers and retailers. Given the main leviable brands are the three largest global brands, namely Coca-Cola, Red Bull and Monster who value global consistency, the increased SDIL rates *based on the current thresholds* are unlikely to encourage reformulation.

Perhaps a better policy would be to either increase the thresholds for the current mid-tier band from 5-8grams to 5-10grams, or to introduce a new threshold for drinks ≥10 grams per 100ml. Such an intervention is more likely to encourage reformulation down from the current 10.6gram – 11gram range of the leviable brands to just below 10 grams. This may seem a

small drop, but it is likely to have a greater calorie reduction impact than any demand side response to the inflation plus increases.

It is likely that coffee and milkshakes with added sugar above the thresholds (currently exempt based on their 75%+ milk content) will lose that exemption. Whilst this move will be unwelcome for brands such as Starbucks, Costa and Friji, given the growth in popularity of these brands and the high calorie content per 100ml (circa 50% higher than regular Coca-Cola) it is a not unexpected policy development. If the exemption is removed it will be interesting to see if they join the reformulator group, or expand the category of leviable brands.

There is also the potential, based on the outputs of the SDIL consultation, that the threshold level these brands, *and all other previously reformulating brands*, will need to reach to avoid incurring the SDIL going forward will be lowered from 5 to 4 grams of sugar per 100ml.

This threshold reduction would not be welcomed by those who reformulated brands in the 2017 / 2018 SDIL response and as described in chapter 2 were 'required' to deliver a further reformulation from 5 to 4.5 grams in 2021 / 2022 to ensure the brands were HFSS compliant (≤ 4.5grams per 100ml). This further drop will arguably result in a further round of reformulation and artwork complexity, for little calorific benefit (the initial reformulation removed 5bn calories a week, this will remove a further 400m calories per week – or circa 300 calories per capita on an annualised basis).

The current marginal 0.5 gram per 100ml difference in thresholds between the SDIL and the NPM (and hence HFSS policy) undoubtedly represents a failure of health policy cohesion. A further 'salami' drop to 4 grams perpetuates this problem and may well induce policy uncertainty amongst producers *and undermine the role of the SDIL as a positive co-ordinating force.*

There is also the potential for unintended consequences. As the 'regular' sugar content is pushed closer towards 'diet' levels, the rationale for having both variants in the market starts to diminish. This creates two policy risks, the first that brand owners wanting to create distinct roles for the variants return to more of a binary full sugar (high threshold) and diet (no levy) approach. The second and arguably greater risk is that as the gap between unlevied regular and diet narrows, consumers consider 'trading-up' from diet to higher calorie alternatives.

There is some descriptive evidence within the lemonade category to support the hypothesis that a further threshold drop could be counter-productive. It is a feature of the lemonade category

that the regular versions now sit at close to, or below 4grams of sugar per 100ml. In lemonade, the diet variants, which are readily available, account for only 33% of total sales volumes. Furthermore, the data shows that as regular lemonades have lowered their sugar levels, the share of sales in diet lemonade has fallen from 40% to 33% over the past 5 years (Circana 2025). This compares to the cola segment where diet accounts for over 70% of total sales and in contrast to the Lemonade segment, continues to grow its share.

Arguably there is a point where the consumer actively chooses to return their consumption to a sugar added drink because the sugar content level is seen as 'low enough'. It is worth noting that with a drop to 4 grams per 100ml, *the traffic light label for sugar on a regular can will turn from red to amber* and the calorie level will drop to about 50 calories. This is some 30% less than a single (not even chocolate coated) digestive biscuit (McVities 2025) and hence the risk of an unintended consumer response. 'The calorie level in this can is now so low, I might as well switch back to the regular variant'.

The comparison between the calorie level in a can of drink and a digestive biscuit brings this discussion to the final part of question 3, namely, what can analysis of the SDIL tell us to inform a broader national food strategy?

The Public Health England (2015) report 'Sugar Reduction – The Evidence for Action' reported that for adults and teenagers some 15% and 12% of their energy intake respectively was coming from sugar. It further reported that for adults and teenagers some 16% and 30% respectively, of this sugar was coming from soft drinks. (2008 – 2012 nutritional surveys PHE 2015).

Arguably this PHE report was highly influential in advancing the SDIL debate, yet what is striking is that even amongst teenagers only 4.5% of their calorie intake was coming from soft drinks, and for adults the percentage was less than 2%, with this *including* the calories from sugar naturally occurring in fruit juice which is considered to have other nutritional benefit. Furthermore, a simple heuristic that factors in the findings of this study (2014 – 2020) would see these levels reduce by just over a third.

This data is not being presented as some sort of defence of the soft drinks industry, but rather as an important context for any future policy that has the objective of delivering calorie (and hence obesity) reduction.

In July 2021 the 'National Food Strategy - an independent review for government' (NFS, 2021) was published. Henry Dimbleby (one of the founders of the Leon food chain) led an advisory panel made up of 24 senior figures from agriculture, industry, academia and non-governmental bodies, to produce a detailed 290 page report entitled 'THE PLAN' with a further 70 pages of recommended actions for government. The report covered a wide range of food related topics from health and obesity to sustainable sourcing and resilience in the food supply chain.

Recommendation #1 was the introduction of a £3 per kg tax on sugar and a £6 per kg tax on salt. The £3 per kg sugar tax – which would translate to circa 30p a litre was proposed to replace the existing 2018 UK SDIL.

'THE PLAN' references the success of the SDIL policy as the main basis for the £3 per kg recommendation. This is somewhat paradoxical as the fundamental reason why the SDIL was so successful was that *it was not introduced as a linear tax.* In setting brand-owners a challenging, but realistic set of landing points to either partially or fully avoid the levy, and then a clear two-year timeframe which created the necessary space to deliver high quality reformulation, the government acted as a powerful co-ordinating catalyst for an industry that was already primed to respond to changing consumer preferences towards sugar.

An interesting question is to consider what the counterfactual outcome might have been *if* a simple £3 per kg linear tax had been introduced in the budget in March 2016. It is fair to assume the four main brands who did not reformulate at 24p a litre would not have reformulated at 30p a litre. The potential action of the reformulators is more difficult to predict. This study has shown that the halving of sugar (from 10 to 5 grams per 100ml) with the sweetness balanced by added sweeteners did not harm the sales of the reformulating group. However, to make such a move under the NFS recommendation, the brand owner would need to embrace the 'double jeopardy' of reformulation *and* passing through cost increases into retail price. For example, in the case of the 2L bottle of 'Fizzy Pop' in Figure 2.11 a reformulation to 5 grams per 100ml would still incur a 30p (2 x 15p a litre) sugar tax impact on COGs. To offset this cost, the brand owner would have to pass-through the 30p into their invoice price, resulting in a likely retail price increase from £1 to £1.36 (including VAT). Furthermore, the brand owner faces the uncertainty of not knowing what their main competition is going to do. If they do reformulate to what level will they go and therefore what is the likely impact on their retail pricing? In such a scenario it is perhaps a better strategy to sit tight, pass-through the tax and double down on driving demand into the diet variants of the brand. This could leave the policy

relying solely on a demand side impact, which would be significant at £3 per kg, but arguably nowhere near as powerful as the 86% of total calorie reduction delivered through reformulation in the SDIL.

Given the earlier comment about a 2L bottle of 'Fizzy Pop' being an affordable treat for households, and the consumption skew towards lower income households found in Berger et al. (2020) this recommendation quickly becomes a regressive tax, which if placed on some 40, rather than 4 main brands, is likely to face a far more significant consumer backlash.

Would the £3 per kg sugar tax be more effective in other food categories, would it incentivise brand owners to reformulate their products? Chocolate is an interesting market to consider with the average UK consumer eating some 8.1kg of chocolate per year (CBI 2022). Based on the Dairy Milk calorie content of 534 Kcal per 100 grams, this translates to some 43,254 annual calories of which about 40% comes from some 4.5kg of added sugar (56 grams of sugar per 100 grams of chocolate).

The average retail price of a 100 gram bag of Dairy Milk chocolate buttons sold across the main UK grocery retailers in October 2025 was £1.95 (Tesco–JS–Asda, hence the 5 ending). A £3 per KG sugar tax would increase the COGs on this bag by 16.8p or some 20p once VAT was added, based on a straight pass-through of the tax. It is hard to see the incentive for the brand owner to reformulate, rather than pass-through the tax-based cost increase, particularly if they assume the whole chocolate industry will on mass pass-through similar price increases.

However, what if instead of a linear tax, a threshold-based policy intervention was put in place and the £3 per KG sugar tax could be avoided either partially or entirely by chocolate producers *reducing their sugar content to say below 50 grams per 100 grams of chocolate?*

Some 6 grams of a reduction (just over 10%) does not seem significant, it could even be regarded as a bit 'every little helps' as far as policy interventions are concerned, *yet it flows through to a national weekly calorie reduction of some 2.5bn calories*[55]. The same threshold-based policy structure could be applied to sugar added to a whole range of cakes, biscuits and other foods. The key is knowing where to set the target level or landing point for the threshold. Based on the different technical challenges involved in reformulation this exact point is likely to vary by product category.

[55] 6 grams of sugar reduction per 100 grams = 24 calories. Multiplied by 8.1kg of annual chocolate consumption = 1,944 calories per year. Multiplied by a UK population of 68m (ONS) = 132.3bn calories or some 2.5bn calories per week.

Finally, on a personal level I have to confess to something of a love / hate relationship with the UK SDIL. I hate remembering the shock and angry helplessness that I felt on the afternoon of the 16th March 2016, and it directly led to undoubtedly the most difficult business decision I faced across my 30 year career, whether to reformulate or not to reformulate a much loved 115 year-old IRN-BRU recipe. During my career, very few business challenges caused me to lose sleep at night, but the SDIL announcement was undoubtedly one of them.

However, I am also very proud of the successful response of the business and the impact this response has then delivered in terms of calorie reduction and its associated public health improvements. Taking 53,000+ annual calories out of the diet of a loyal consumer without them even knowing, or knowing but having no impact on their enjoyment of the brand is something to celebrate.

A 'spoonful of sugar levy did help the calories go down' if not in the most delightful way, then at least in a highly effective way. I do however fear, that encouraged by the undoubted success of the policy, too much medicine will be given to the UK soft drinks industry and the complex nuances of the SDIL's success, many of which are set out in this thesis, may well be lost.

Appendix

Table A1 Top 100 Grocery brands surveyed for the price point observations in Ch. 1

Ranking & Brand		Value £m*
1.	Cadbury	1,855
2.	Coca Cola	1,616
3.	Walkers	1,251
4.	Nestle	1,165
5.	Pepsi	778
6.	Warburtons	757
7.	Heinz	727
8.	Purina	689
9.	Red Bull	577
10.	Birds Eye	561
11.	Kelloggs	519
12.	Lucozade	517
13.	Monster	500
14.	Nescafe	466
15.	McVities	460
16.	McCain	420
17.	Muller	410
18.	Arla	408
19.	Andrex	401
20.	Fairy	387
21.	Lurpack	375
22.	Danone	370
23.	Hovis	353
24.	Lindt	339
25.	Fanta	292
26.	Pringles	284
27.	Robinsons	268
28.	Cathedral City	268
29.	Innocent	257
30.	Doritos	252
31.	Magnum	239
32.	Wrigley	235
33.	Alpro	232
34.	Galaxy	223
35.	Haribo	221
36.	Maltesers	201
37.	Tropicana	200
38.	Jacobs	196
39.	Whiskas	187
40.	Persil	186

Ranking & Brand	Value £m*
41. Weetabix	186
42. Youngs	184
43. Volvic	181
44. Mr Kipling	179
45. Evian	176
46. Yeo Valley	175
47. Schweppes	173
48. Pedigree	173
49. Dairylea	170
50. Charlie Bigham's	169
51. Starbucks	169
52. Richmond	165
53. Lenor	162
54. Quaker	159
55. Quorn	158
56. Kinder	156
57. Hulla Hoops	155
58. Highland Spring	154
59. Ariel	153
60. Dr Pepper	151
61. McCoys	150
62. Batchelors	147
63. Comfort	146
64. Good Boy	144
65. Buxton	140
66. Anchor	138
67. Hellman’s	138
68. Ben & Jerrys	136
69. Chicago Town	135
70. Rowntrees	135
71. IRN-BRU	135
72. Kleenex	134
73. Bisto	134
74. Cushelle	132
75. Prince	132
76. Pot Noodle	132
77. Kenco	129
78. Kingsmill	129
79. John West	127
80. Ferrero	126

Ranking & Brand	Value £m*
81. Yorkshire Tea	125
82. Flora	122
83. Ben's Original	120
84. Old El Passo	120
85. Duracell	119
86. Aunt Bessies	118
87. Plenty	117
88. Ribena	117
89. Ginsters	116
90. Finish	116
91. Vimto	114
92. Pepperami	113
93. Philadelphia	112
94. Fox's	112
95. Pizza Express	111
96. Rustlers	111
97. Fever Tree	108
98. Maynard Bassets	107
99. Dettol	104
100. Napolina	103

Table A2 Event-study estimates: effect of reformulation

	(1) (Log) Calories	(2) (Log) Volume	(3) Cal per 100m	(4) £-Price per Litre
$t-6$	-0.030	-0.048	0.660*	-0.005
	(0.038)	(0.043)	(0.364)	(0.015)
$t-5$	-0.103**	-0.131**	0.959*	0.028
	(0.047)	(0.051)	(0.479)	(0.020)
$t-4$	0.053	0.021	0.998	-0.040***
	(0.042)	(0.036)	(0.593)	(0.012)
$t-3$	0.040	0.001	1.134	-0.023
	(0.042)	(0.035)	(0.752)	(0.016)
$t-2$	0.043	-0.003	1.296	-0.015
	(0.044)	(0.038)	(0.902)	(0.010)
$t-1$	0.054	0.010	1.144	-0.012
	(0.048)	(0.047)	(1.052)	(0.017)
$t+1$	-0.180**	0.050	-9.624***	-0.025**
	(0.078)	(0.066)	(2.035)	(0.013)
$t+2$	-0.599***	0.017	-20.908***	-0.051***
	(0.077)	(0.048)	(3.394)	(0.014)
$t+3$	-0.686***	-0.070	-21.164***	0.010
	(0.072)	(0.044)	(3.835)	(0.013)
$t+4$	-0.646***	-0.042	-20.865***	-0.016
	(0.086)	(0.052)	(4.082)	(0.016)
$t+5$	-0.675***	-0.073	-21.014***	-0.028**
	(0.096)	(0.067)	(4.497)	(0.013)
$\geq t+6$	-0.684***	-0.127	-20.843***	-0.015
	(0.122)	(0.079)	(6.206)	(0.031)
R^2	0.97	0.96	0.96	0.97
N	6,548	6,548	6,548	6,548
Week Fixed-Effects	Yes	Yes	Yes	Yes
Brand Fixed-Effects	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are adjusted for clustering at the brand level, $*$ p < 0.05, $**$ p < 0.01, $***$ p < 0.001 This table shows regression results corresponding to the event-study specification set out in equation Ch2 (1). In all specification, we weight by litre sales. Only observations pertaining to brands that reformulated their beverages are part of the estimation sample. We regress our outcomes of interest, (log) calories consumed, (log) sales volume, calorie count per 100ml, and price (in £ per litre) on a set of 4-week leads and lags relative to each brands reformulation date. The reference period is $\leq t-7$. Coefficients are transformed into the percentage changes in 2.25 such that $\% - \text{change} = e(\delta) - 1$.

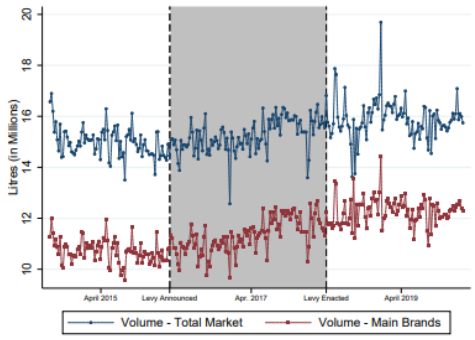
Table A3 Event-study estimates: effect of reformulation

	(1) (Log) Calories	(2) (Log) Volume	(3) Cal per 100m	(4) £-Price per Litre
$t-6$	-0.0588	-0.058	0.050	-0.004
	(0.046)	(0.046)	(0.068)	(0.013)
$t-5$	-0.107*	-0.108*	0.052	0.039**
	(0.060)	(0.061)	(0.117)	(0.014)
$t-4$	0.011	0.011	0.029	-0.021
	(0.049)	(0.050)	(0.090)	(0.016)
$t-3$	0.054	0.055	-0.018	-0.009
	(0.051)	(0.052)	(0.083)	(0.016)
$t-2$	0.027	0.027	-0.001	-0.004
	(0.059)	(0.059)	(0.079)	(0.014)
$t=0$	-0.227***	0.055	-11.157***	0.005
	(0.057)	(0.054)	(0.888)	(0.012)
$t+1$	-0.636***	0.037	-22.593***	-0.041***
	(0.046)	(0.042)	(1.489)	(0.011)
$t+2$	-0.714***	-0.031	-22.860***	-0.007
	(0.045)	(0.041)	(1.476)	(0.011)
$t+3$	-0.608***	-0.076	-22.736***	0.030
	(0.068)	(0.067)	(1.500)	(0.019)
$t+4$	-0.699***	-0.036	-22.785***	-0.002
	(0.079)	(0.074)	(1.949)	(0.015)
$\geq t+5$	-0.729***	-0.069	-23.483***	-0.009
	(0.107)	(0.109)	(.879)	(0.012)
R^2	0.98	0.97	0.99	0.97
N	6,684	6,684	6,684	6,684
Week Fixed-Effects	Yes	Yes	Yes	Yes
Brand Fixed-Effects	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses are adjusted for clustering at the brand level, $*$ p < 0.1, $**$ p < 0.05, $***$ p < 0.01 This table shows regression results corresponding to an event-study specification estimated using the approach outlined in Sun and Abraham (2021). Only reformulating brands are part of the sample which is truncated at the date on which the last brand reformulates (29 April 2018). In all specification, we weight by litre sales. Only observations pertaining to brands that reformulated their beverages are part of the estimation sample. We regress our outcomes of interest, (log) calories consumed, (log) sales volume, calories per 100ml, and price (in £ per litre) on a set of 4-week leads and lags relative to each brands reformulation date. The two dropped leads are t = −1 and t < −6. Coefficients are transformed into percentage changes in Figure 2.26 according to % change = e δ − 1.

Figures A1-8 Comparison between Top 100 soft drinks brands - total market by segment

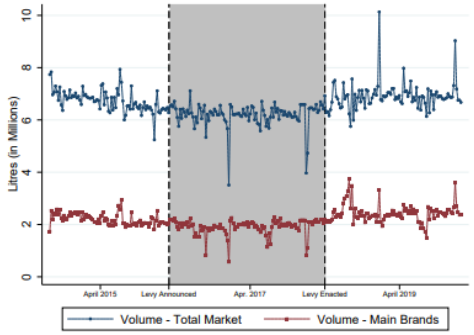
Figure A1 OFC : Top 100 Brands Comparison vs Total Market



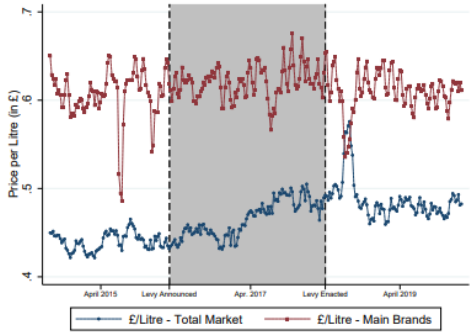
Volume

Price

Figure A2 Lemonade : Top 100 Brands Comparison vs Total Market

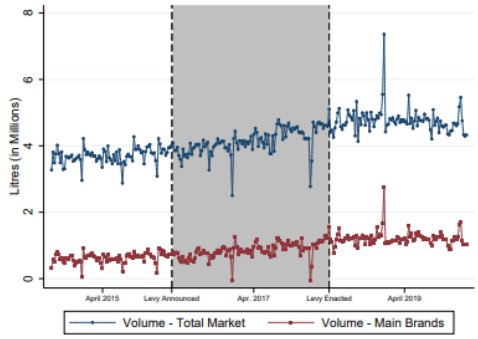


Volume

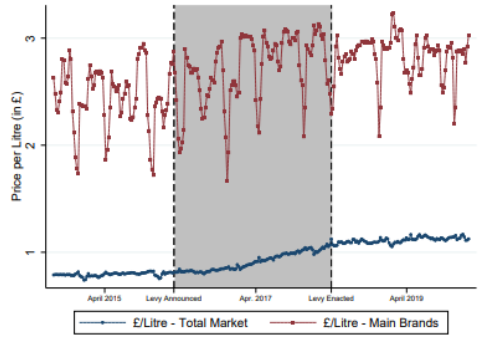


Price

Figure A3 Mixers : Top 100 Brands Comparison vs Total Market

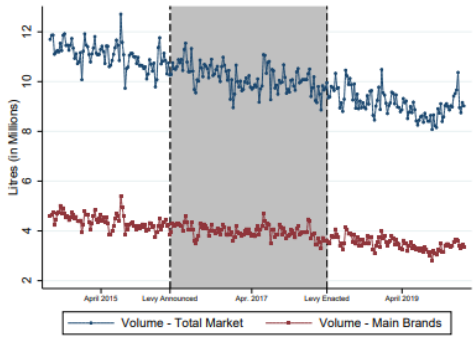


Volume



Price

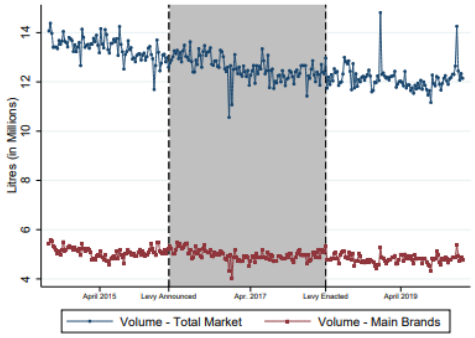
Figure A4 Fruit Drinks : Top 100 Brands Comparison vs Total Market



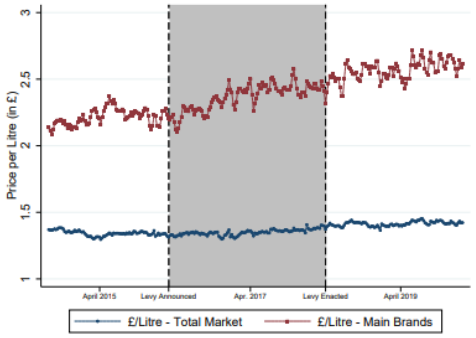
Volume

Price

Figure A5 Fruit Juice : Top 100 Brands Comparison vs Total Market

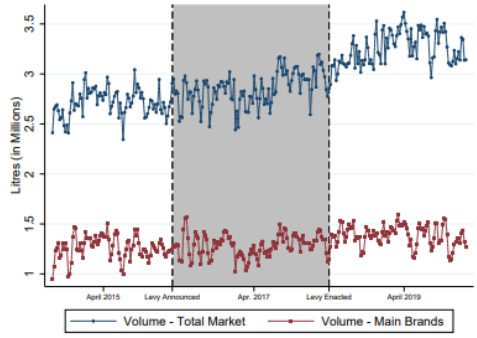


Volume

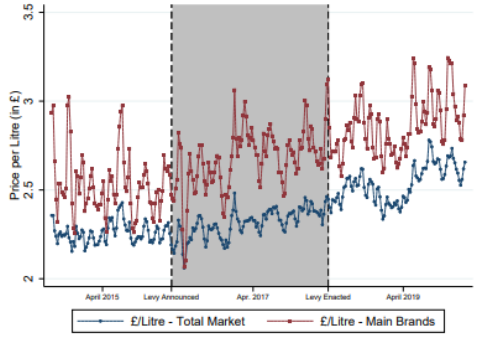


Price

Figure A6 Dairy : Top 100 Brands Comparison vs Total Market

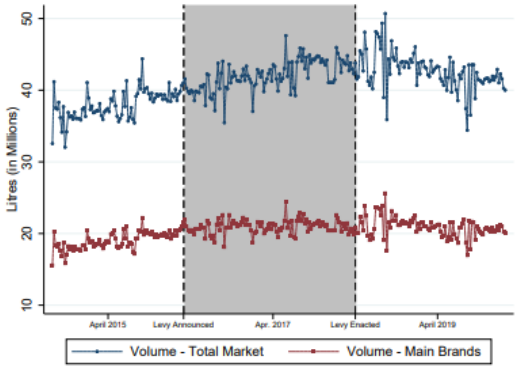


Volume

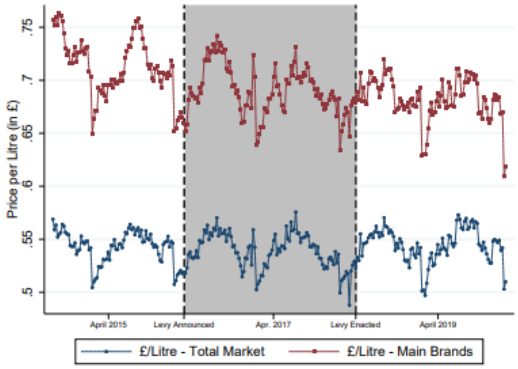


Price

Figure A7 Water : Top 100 Brands Comparison vs Total market

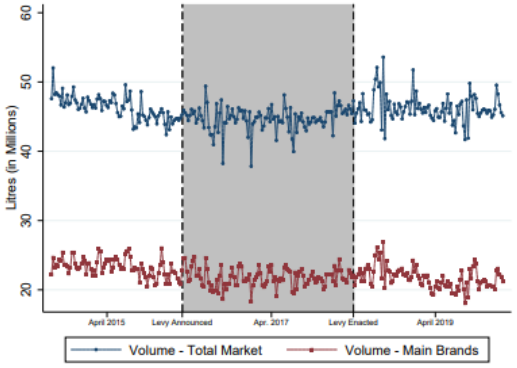


Volume

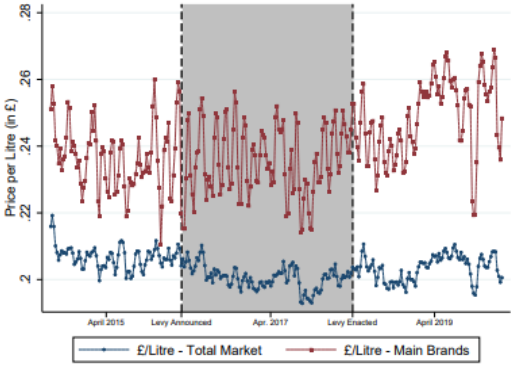


Price

Figure A8 Squash : Top 100 Brands Comparison vs Total Market



Volume



Price

Figure A9 Water as a control group

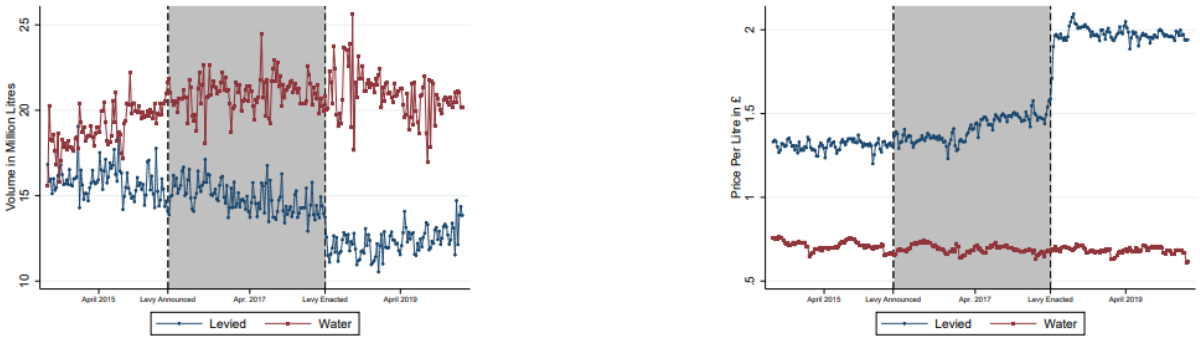
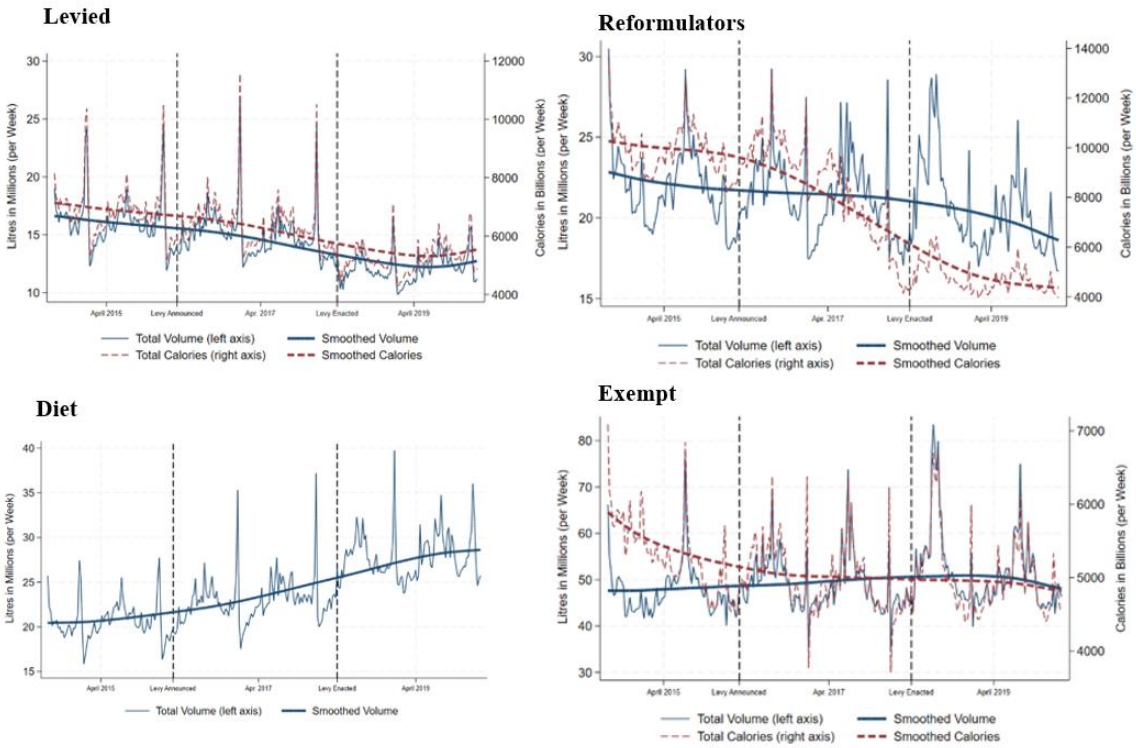


Table A2 DiD analysis with water as the control group

	(1)	(2)	(3)	(4)
	Aggregate Level		Brand Level	
	Price	Volume	Price	Volume
Levied × *Post*	0.623***	-0.253***	0.325***	0.009
	(0.010)	(0.014)	(0.078)	(0.262)
R^2	0.994	0.924	0.991	0.910
N	576	576	4896	4691

Notes: Heteroscedasticity-robust standard errors in parentheses, $*$ p < 0.10, $**$ p < 0.05, $***$ p < 0.01 This table shows the results of a differences-in-differences specification where levied brands are the treatment group and water brands serve as control group. Columns (1) and (2) conduct the analysis at the aggregate level, i.e. with a single treatment and a single control group. Column (3) and (4) show the results at the brand-level, i.e. the with the brand-week as the unit of observation. Both specifications contain week fixed-effects, the brand-level specification also contains brand fixed-effects. The main coefficient of interest is an interaction between a dummy which indicates whether a product is in the levied category and a post dummy that is equal to 1 for periods after the levy was enacted.

Figure A10 Figure showing a graphical comparison of all 4 SDIL categories



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