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Jaakko Markkanen

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Industrial Organization Studies on Pharmaceutical Markets

Jaakko Markkanen

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Avainsanat toimialan taloustiede, lääkemarkkinat, sääntely

Tämä väitöskirja koostuu kolmesta julkaisemattomasta esseestä. Ensimmäinen essee koskee viitehintasääntelyn vaikutuksia Pohjoismaiden lääkemarkkinoilla. Tutkimuksessa hyödynnetään kvasikokeellisia tutkimusasetelmia yhdistämällä eri lääkemarkkinoita tuotteiden vaikuttavien aineiden perusteella. Tutkimuksen tulokset osoittavat, että tiukempi hintasääntely laskee annoskohtaisia lääkemenoja jopa 40 % vaikuttamatta haitallisesti lääkeaineiden saatavuuteen tai kulutukseen. Sääntelyn vaikutus kuluttajien kannustimien on tärkeää, mutta järjestelmät, jotka vaikuttavat sekä kuluttajien että tuottajien kannustimiin toimivat parhaiten.

Toinen essee käsittelee lääketaksasääntelyn vaikutuksia tukkumyynti- ja vähittäismyyntihintoihin Suomessa. Tutkimuksessa hyödynnetään sekä kvasikokeellista tutkimusasetelmaa että rakenteellista mallintamista. Tutkimus osoittaa, että lääketaksan aleneminen johtaa tukkumyyntihintojen nousuun, ja vain puolet lääketaksan alentamisesta siirtyy vähittäishintoihin. Tutkimuksessa selvitetään myös, kuinka muutokset arvonlisäverokannassa voisivat tasapainottaa lääketaksan laskemisen vaikutuksia markkinoilla.

Kolmannessa esseessä tutkitaan apteekkimarkkinoiden sääntelyn keventämisen vaikutuksia Suomessa. Simulaatiotulostemme perusteella nykyinen määrä- ja sijaintisääntely suosii nykyisiä apteekkareja kuluttajien kustannuksella. Vaikka sääntelyä perustellaan apteekkipalveluiden alueellisen saatavuuden takaamisella, tuloksemme osoittavat, että sääntelyn purkaminen hyödyttäisi lähes kaikkia kuluttajia. Sääntelyn purkaminen lisäisi erityisesti apteekkien määrää kaupungeissa, kun taas maaseudulla hyödyt jäisivät vähäisemmiksi. Vaikka kuluttajien hyvinvointi kasvaa merkittävästä, kiinteiden kustannusten nousu ja työvoiman tuottavuuden heikkeneminen vähentävät uudistuksen yhteiskunnallisia hyötyjä. Kokonaishyvinvoinnin näkökulmasta markkinoille tulisi siis liikaa uusia apteekkeja.

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ABSTRACT

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Keywords industrial organization, pharmaceutical markets, regulation

This thesis comprises three unpublished essays. The first essay analyzes the effectiveness of consumer choice policies in the Nordic pharmaceutical markets. Using quasi-experimental methods and data matched across countries by active ingredients, the results show that pharmaceutical expenditure per dose decreases by 40% under stricter pricing regimes, without adversely affecting pharmaceutical availability or consumption. Regimes that increase consumer incentives are effective, but those that address both consumer and producer incentives are the most successful.

The second essay examines the impact of retail markup regulation on wholesale and retail prices in the Finnish pharmaceutical market. Employing both reduced form and structural analyses, I find that a reduction in pharmacy markups leads to increased wholesale prices, with only half of this increase passed on to retail prices. The study also suggests that adjustments in VAT rates could counterbalance the increased manufacturer revenues resulting from lower retail markups.

The third essay evaluates the impact of relaxing entry regulations in the Finnish pharmacy market. Our simulation results show that the existing entry restrictions primarily benefit incumbent pharmacists at the expense of consumers. Furthermore, although entry regulations are motivated by the goal of ensuring equal access to local pharmacy services, our results suggest that almost all consumers benefit from deregulation. The number of pharmacies increases, particularly in urban areas, whereas rural areas and regions with older populations benefit less. However, increases in fixed costs and reduced labor productivity outweigh consumer surplus gains, indicating excessive entry from a social welfare perspective.

Preface

> Is it not a strange fate that we should suffer so much fear and doubt for so small a thing? So small a thing!
>
> ---
>
> Boromir, "The Breaking of the Fellowship,"
> J.R.R. Tolkien, *The Lord of the Rings*

The work in this thesis represents countless wasted hours, mistakes, and anxiety. At the same time, it has brought some moments of adventure and excitement. Fortunately, I have been privileged to have the support of many people along the way.

I would like to thank my supervisor, Professor Otto Toivanen, whose guidance and positive feedback have been crucial for my work. I am also grateful to my committee members, Professor Mika Kortelainen and Senior Researcher Markku Siikanen, for their support. Otto, Mika, and Markku are my co-authors of the first essay in this thesis, and working with them has been invaluable to my development as a researcher. Markku, in particular, has been an exceptional advisor, encouraging me to pursue this career and teaching me the hidden curriculum of academia. I wish every PhD student could have a mentor and a friend like Markku.

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One of the best parts of my PhD journey was the X308 Society. I have truly enjoyed our discussions and wild ideas with Arttu Kahelin, Eero Mäenpää, Mikael Mäkimattila, and Antto Jokelainen, and I look forward to many more moments where brilliance and madness blur together. Special mention to Antto, with whom I worked on the last essay—he is one of the hardest-working people I know. Some of our best ideas came to life at Kotiharjun sauna.

I thank Topi Hokkanen for our correspondence over the years. I also thank my coauthors in other projects, Milla Hägg, Matias Pousi and Nelli Valmari. From the wider Helsinki GSE community, I am grateful to Tanja Saxell, Tuomas Markkula, Eero Nurmi, Helena Rantakaulio, and Hung Le for their contributions to the IO group. Lastly, I wish to express my sincere gratitude to my new colleagues at Etla for their warm welcome and for embracing me as part of the team.

I dedicate this thesis to my family. I am fortunate to have received so much support from my mom and dad and from my siblings, Aapo, Juuli, Kaisa, and Kalle. You remind me that the most important things in life lie outside of academia. My history with Kalle goes back literally to before we were born, and he remains my first reader for every paper.

I am most of all grateful to my partner in life, Salla. Her love and support have been my greatest strength throughout this journey. Salla has taught

me kindness and made me a better person; she has saved and redeemed me in ways I cannot fully express here.

Helsinki, December 23, 2024,

Jaakko Markkanen

Contents

List of Essays

This thesis consists of an overview and of the following essays.

I Kortelainen, Mika and Markkanen, Jaakko and Siikanen, Markku and Toivanen, Otto. The Effects of Price Regulation on Pharmaceutical Expenditure and Availability. *Unpublished manuscript*.

II Jaakko Markkanen. Passthrough of Retail Price Regulation in the Market for Pharmaceuticals. *Unpublished manuscript*.

III Jokelainen, Antto and Markkanen, Jaakko and Leppälä, Samuli and Siikanen, Markku and Sipiläinen, Matti and Toivanen, Otto. Free Entry and Social Inefficiency in Regulated Pharmacy Markets. *Unpublished manuscript*.

Author's Contribution

Essay I: "The Effects of Price Regulation on Pharmaceutical Expenditure and Availability"

Kortelainen, Siikanen and Toivanen developed the idea and obtained the data. Markkanen and Siikanen conducted the empirical analysis. The authors contributed equally to the rest of the paper.

Essay II: "Passthrough of Retail Price Regulation in the Market for Pharmaceuticals"

Solo authored.

Essay III: "Free Entry and Social Inefficiency in Regulated Pharmacy Markets"

Leppälä and Sipiläinen obtained the data from FCCA. All authors participated in early stages discussions on how to proceed and how to develop the project, with Sipiläinen conducting preliminary descriptive analyses of data. Jokelainen, Leppälä, Markkanen, Siikanen, and Toivanen developed the econometric framework, the counterfactual analysis and the structure of the paper. Jokelainen and Markkanen conducted the empirical analysis.

Markkanen and Siikanen drafted the manuscript. Jokelainen, Leppälä, Markkanen, Siikanen, and Toivanen edited the manuscript.

Introduction

This doctoral dissertation consists of three unpublished essays, all of which consider the effects of regulation in pharmaceutical markets. Each essay is independent and self-contained, and employs a different methodology to assess how different regulations influence market dynamics and consumers. Together, the essays demonstrate how reduced-form and structural methods in industrial organization research can be applied to study the market for pharmaceuticals.

The pharmaceutical sector is a large and growing market worldwide. In 2023, the global market for pharmaceuticals amounted to $1.6 trillion, with a 5-year compound annual growth rate of 7.3% (IQVIA 2024). Pharmaceutical markets are also among the most heavily regulated in the world. Products are regulated at every stage of their lifecycle, from development to eventual, though uncertain, sale in pharmacies. Not all drug development is successful, and many products fail to receive market authorization, even if they have completed clinical trials (Scott Morton and Kyle 2011). The sheer size of the market, much of which is publicly funded, motivates governments to regulate and monitor to ensure safety, effectiveness, and control spending (Panteli et al. 2016).

The first two essays of this thesis focus on wholesale and retail price regulation in the pharmaceutical industry. In the first essay titled “The Effects of Price Regulation on Pharmaceutical Expenditure and Availability”,

which is coauthored with Mika Kortelainen, Markku Siikanen and Otto Toivanen, we examine different Reference Pricing Systems (RPSs) adopted in Finland, Sweden, Norway, and Denmark during the early 2000s. We apply a Difference in Differences (DID) framework as our empirical strategy to estimate the effects of regulation on pharmaceutical expenditure and product variety. The focus of the second essay of this dissertation, "Passthrough of Retail Price Regulation in the Market for Pharmaceuticals", is on studying the transmission of retail markup regulation and taxation to wholesale prices. I estimate a structural model of statin demand to study the transmission of government-regulated pharmacy markups and Value Added Tax (VAT) in the vertical supply chain. Both of these essays are directly related to the strategic responses of pharmaceutical manufacturers to price regulation.

The first essay studies Reference Pricing (RP), which is a common regulatory measure in the pharmaceutical market. Regulators use RP to cap consumer reimbursement levels to a so-called reference price to curb pharmaceutical spending. If a consumer purchases a product priced above the reference price, he or she will have to pay the price differential completely Out-of-Own Pocket (OOP). This incentivizes consumers to substitute expensive products for products priced at or below the reference price, making consumers more price sensitive. In addition to the first-order effect on savings, RPSs also incentivize companies to lower their prices in response to more elastic demand. In most cases, RP is combined with Generic Substitution (GS), a policy that allows consumers to choose an identical product to the one prescribed and requires pharmacies to actively encourage this substitution. Both RP and GS can be implemented in various different ways, which is a major theme of the first essay in this thesis. Studying different variations of similar regulatory systems in the Nordics allows us to compare the effectiveness of the policies.

My second essay focuses on the regulation of retail prices in pharmacies.

In Finland, pharmacies cannot set their own prices for pharmaceuticals. Instead, the government decides the markups of pharmacies, so that retail prices are calculated from wholesale prices with a formula set by regulation. Since regulation also forbids price discrimination at the wholesale level, pharmaceuticals have uniform prices at the national level. In my second essay, I argue that these regulated markups have similar effects to a VAT, so that part of the incidence falls on the pharmaceutical manufacturers in the form of lower wholesale prices. This allows me to study the trade-off between markup regulation and VAT, and to evaluate the rationale behind the reduced VAT rates for pharmaceuticals that exist in many countries.

In addition to price regulation, many countries regulate the pharmacy network through controlled entry. These restrictions are intended to promote access to quality pharmacy services. My third essay, which is co-authored with Antto Jokelainen, Samuli Leppälä, Markku Siikanen, Matti Sipiläinen, and Otto Toivanen, studies pharmacy regulation. In this essay, we examine the Finnish pharmacy market, specifically the effects of pharmacy entry regulation on pharmacy service availability and consumer welfare. We employ a structural model for pharmacy choice and a counterfactual simulation to evaluate how market deregulation would affect the market structure in the retail pharmaceutical sector. We estimate how the pharmacy network would change under free entry, and how this would affect different consumer groups.

In the following, I provide summaries of each essay. These summaries are meant to present the main results of each essay as well as to discuss their respective contributions to the economic literature and public policy.

Essay I: The Effects of Price Regulation on Pharmaceutical Expenditure and Availability

This essay is co-authored with Mika Kortelainen, Markku Siikanen and Otto Toivanen. We analyze the impact of price regulation policies on pharmaceutical expenditure and availability using quasi-experimental methods. We focus on consumer choice reforms, specifically GS and RP policies, implemented in generic pharmaceutical markets in the Nordic countries. We use a detailed data set on monthly revenues and quantities of drugs bought by community pharmacies. It includes product characteristics, sales value, and volume of each pharmaceutical package sold. Sales values are measured in wholesale prices, and volumes are measured in Defined Daily Dosages (DDDs) for each active ingredient. In contrast to existing literature that uses mostly within-country data, we match the treatment and control groups across countries based on active ingredients. By employing DID methods on market-level observations, we evaluate the effectiveness of these policies. While the existing literature has focused mainly on the effects of regulation on prices, we construct a novel outcome variable to capture both of these effects. This variable, average expenditure, is calculated by dividing the total monetary sales by the total number of doses sold.

Our findings indicate a significant reduction in pharmaceutical expenditure per dose when transitioning from the least strict to the strictest regimes. For example, switching from Voluntary Generic Substitution (VGS) to Product of the Month Auction (Auction-IRP) led to a reduction of up to 40% in expenditure. Overall, reforms targeting consumer incentives proved effective in reducing expenditure, but those addressing both consumer and producer incentives achieved the greatest impact.[1] Spe-

1. In a VGS system, substitution to a cheaper interchangeable product is possible, but requires an active decision from the prescribing physician. Auction-IRP is an RPS where the lowest auction bid sets the reference price, and customers pay the full price if they choose any other product.

cific policy changes, such as Finland's 2009 transition from GS to IRP and Sweden's 2009 move to Auction-IRP, showed substantial expenditure reductions of 13% and 29%, respectively.

The reductions in expenditure were often larger than the decreases in average prices. In the case of the Swedish Auction-IRP reform, while average prices decreased by 14%, the expenditure per dose decreased more significantly. This discrepancy can be attributed to the reallocation of demand towards cheaper products under stricter regulatory regimes. Our analysis did not find evidence of adverse effects on the availability of pharmaceutical products. The number of product names on the market remained stable or even increased slightly in some cases. Similarly, the quantity of pharmaceuticals consumed did not show a change or a slight increase, suggesting that stricter regulations did not negatively impact overall consumption. This indicates that stricter regulations can introduce savings without harming market supply, allowing consumers continued access to their prescribed products or their substitutes.

Our study emphasizes the importance of consumers' financial incentives in driving the effectiveness of GS and RP policies. For instance, the Finnish 2003 VGS to GS reform had little impact on expenditure due to the lack of consumer incentives.[2] Conversely, the success of stricter regimes such as the Swedish Auction-IRP demonstrates that combining maximum-price regulation with consumer incentives can significantly reduce expenditure without compromising product availability.

Our empirical strategy is based on matching control groups from comparable markets in neighboring countries. This approach allows us to isolate the effects of the reforms from other external factors. One of the methodological considerations in our study is the Stable Unit Treatment Value Assumption (SUTVA), which requires that the treatment status of

2. In the Finnish GS system, pharmacies are required to offer substitution if a cheaper interchangeable product is available. However, consumers receive the same reimbursement rate even if they decline substitution.

one product does not affect the potential outcomes of other products. We address this by focusing on market-level outcomes rather than individual product prices, an approach that internalizes equilibrium effects and potential spillovers within markets. This approach ensures that our estimates capture the true impact of regulatory changes without the bias that could arise from competition between products within the same market or active incredient.

We find no evidence of adverse effects on market sructure resulting from stricter price regulation in the short or medium term. In contrast, the number of product names on the market remained stable or even increased slightly after regulatory changes. This finding contrasts with concerns raised in the literature that price regulations could lead to reduced availability of pharmaceuticals due to decreased profitability for manufacturers (Kyle 2007; Lakdawalla 2018). Our results suggest that stricter price regulations can coexist with a robust market in terms of product availability. Studies such as those by Yurukoglu, Liebman, and Ridley (2017) have documented concerns about pharmaceutical shortages due to consolidation and fierce price competition. However, our analysis did not find such negative impacts, indicating that well-designed price regulations can mitigate these risks while achieving cost reductions.

Our findings contribute to the literature by providing robust quasi-experimental evidence on the effectiveness of pharmaceutical price regulation in a multi-country context. Previous research has predominantly examined the impacts of GS and RPS reforms on drug prices within specific markets (Brekke, Holmas, and Straume 2011; Kaiser, Mendez, Rønde, and Ullrich 2014; Herr and Suppliet 2017). Our results contribute to the literature by facing the limitations of these studies, which often use data and controls from the same market, restricting the ability to compare different regulatory regimes across multiple markets. Our results align with the findings of Duggan and Scott Morton (2010) and Einav, Finkelstein, and

Williams (2016) on the importance of consumer incentives in reducing pharmaceutical expenditure. In general, our study demonstrates that price regulation policies, particularly those that integrate strong consumer and producer incentives, are effective tools for reducing pharmaceutical expenditure. These policies achieve significant savings without negatively impacting product availability or consumption levels.

On average, our results should generalize well for most off-patent pharmaceutical markets at the active ingredient level. However, our results are less likely to generalize to larger countries with bigger drug markets. Nordic countries make up only a small share of the overall global pharmaceutical market, so the cost-saving policies enacted in these countries are unlikely to affect future pharmaceutical product development and innovation. If larger countries enact similar policies, it could lead to significant changes in market structure and the availability of new pharmaceutical treatments.

Essay II: Passthrough of Retail Price Regulation in the Market for Pharmaceuticals

In this essay, I study the transmission of pharmacy mark-ups to retail prices and the relationship between retail mark-ups and VAT rates in Finland. I use both a reduced form DID strategy and a structural model to estimate the passthrough rate. My reduced-form evidence shows that pharmaceutical manufacturers respond to a decrease in regulated pharmacy mark-ups by increasing their wholesale prices. By estimating a structural model of pharmaceutical supply and demand using data from the Finnish statin market, I find that only half of the decrease in the pharmacy mark-up was transferred to retail prices. In addition, I show that the government can address the increase in manufacturer revenues by increasing the VAT rate for pharmaceuticals.

The Finnish pharmaceutical market features a vertical supply chain where upstream manufacturers set wholesale prices at the national level, and downstream retailers, or pharmacies, distribute drugs to consumers. Retail prices of pharmaceuticals are regulated by the government as a linear function of wholesale prices, with a 10% VAT applied to the retail price. In 2014, Finland reformed the system to reduce pharmacy mark-ups, aiming to save on pharmaceutical expenditure, which is largely covered by the public sector. Since the passthrough rate was less than 100%, pharmaceutical manufacturers captured part of the savings by increasing their wholesale prices, leading to higher profits.

The empirical analysis in my second essay uses the same sales data as in the first essay. In my DID specification, I use monthly price data to estimate the effects of a decrease in pharmacy retail markups in 2014. Due to regulation, manufacturers could not increase the wholesale prices of all products to capture a share of the price increase. I use these products as my control group, while my treatment group consists of products whose wholesale prices could be increased. Using the control group as a baseline for the case of full pass-through, I obtain an estimate of 28% for the average pass-through rate. MacKay, Miller, Remer, and Sheu (2014) discuss the limitations of reduced-form estimates in capturing the true passthrough rate, emphasizing that these estimates may be biased unless the passthrough is constant.

The main analysis of the second essay consists of the estimation of a structural model of supply and demand of the statin market in Finland. This framework is based on a BLP-like demand system (Berry 1994; Berry, Levinsohn, and Pakes 1995; Conlon and Gortmaker 2020). Furthermore, previous studies have explored various aspects of passthrough. Weyl and Fabinger (2013) show that under imperfect competition, passthrough depends not only on demand elasticities, but also on the curvature of demand. Miravete, Seim, and Thurk (2023) study the passthrough properties in

common discrete choice models of demand, showing that traditional multinomial logit models can truncate these rates, while random coefficient models allow more flexible forms of demand.

In my structural models, I aggregate the sales data to the quarterly level. My main specifications yield an average passthrough rate of approximately 58%. This implies that manufacturers benefited significantly from the policy change, increasing their profits by more than four million euros (5.84%) during 2014–2017 in the statin market alone. However, consumers and the public sector saved more than five million euros combined (1.81%) in pharmaceutical expenditure. Pharmacy profits declined by ten million euros (12.90%). Thus, the decrease in pharmacy mark-ups effectively transferred rents from downstream pharmacies to consumers and upstream drug manufacturers.

In my other counterfactual analysis, I change the VAT rate together with pharmacy markups. With a VAT increase to 14%, manufacturer profits rose by 1.79%, expenditure decreased by 0.52%, and pharmacy profits fell by 13.41%. However, a further increase in VAT to 24% resulted in a 7.20% decrease in manufacturer profits, a 2.66% increase in expenditure, and a 28.33% reduction in pharmacy profits. These simulation results imply that the government can compensate for the dynamic responses of pharmaceutical manufacturers in response to markup changes by changing the VAT rate. The results also suggest that countries without a significant pharmaceutical manufacturing sector could reduce the social cost of pharmaceuticals by increasing their VAT rate. This essay contributes to the literature on passthrough and tax incidence, as well as the reduced-form literature studying the effects of regulation in pharmaceutical markets, by providing evidence of the effects of pharmacy mark-up regulation on both retail and wholesale prices.

My results also contribute to the policy discussion on pharmaceutical retail price regulation and pharmacies. The findings demonstrate that

reduced VAT rates for pharmaceuticals benefit drug manufacturers. In small economies without a large pharmaceutical manufacturing industry, this policy can actually increase the social cost of pharmaceutical care because it raises the wholesale prices of pharmaceuticals. Additionally, my results show that policymakers easily overestimate the savings from tighter markup regulation if they assume full passthrough.

Essay III: Free Entry and Social Inefficiency in Regulated Pharmacy Markets

This essay is co-authored with Antto Jokelainen, Samuli Leppälä, Markku Siikanen, Matti Sipiläinen, and Otto Toivanen. We study the impact of potential entry deregulation in the Finnish pharmacy sector. We study how removing current entry restrictions would affect different demographic groups and geographic locations. The Finnish pharmacy sector is regulated to ensure equal access to services throughout the country. However, deregulation could result in an uneven distribution of services, potentially disadvantaging certain areas and consumer groups. To model these effects, we estimate spatial demand for pharmacy services, develop a production model to determine costs, and simulate a free entry counterfactual scenario.

Our research builds on the existing literature on market entry and deregulation. Theoretical works by Spence (1976) and Dixit and Stiglitz (1977) analyze the implications of fixed costs and monopolistic competition on optimal product variety, suggesting that the market structure under free entry may not be socially optimal. Additionally, Mankiw and Whinston (1986) demonstrates that in homogeneous product markets, such as the pharmacy sector in Finland, imperfect competition often leads to excessive entry. The key insight is that, at the margin, entry can be more profitable for the entrant than for society, as the entrant steals customers from

incumbent firms while imposing additional fixed costs on society.

The implications for the Finnish pharmacy sector are clear: With inelastic pharmaceutical demand, regulated prices, and significant fixed costs, free entry is likely to be socially suboptimal. Since aggregate demand is inelastic and pharmacies cannot compete on price, welfare improvements depend on travel-time savings, with limited market expansion from new pharmacy visits. Consequently, each new entrant primarily takes customers from existing pharmacies while increasing the overall costs of the sector.

We base our demand model on the work by Ellickson, Grieco, and Khvastunov (2020). We contribute to the literature by incorporating random coefficients for distance, using travel times for our distance measures, and by including demographic variation in our measurement for market potential. Combined, our modeling choices allow for a more accurate representation of substitution patterns among different consumers. Our model for the supply of pharmaceutical services is based on a Leontief-production function where pharmacies minimize their costs by choosing their optimal inputs for labor and material costs, where the latter represents pharmaceutical purchases at wholesale prices. The functional form of our model requires, realistically, that pharmacies cannot substitute labor with wholesale purchases. Our demand model estimations imply that consumers dislike longer travel times to pharmacies, and that substitution from the inside goods (choosing some pharmacy) to the outside good (choosing no pharmacy) is limited. Our production function estimates imply small economics of scale for labor inputs.

The final component of our structural model involves estimating the fixed costs associated with pharmacy service production. In the current equilibrium, where the econometrician cannot directly observe fixed costs, profitable pharmacies must have fixed costs that are strictly less than their profits before accounting for these costs; otherwise they would exit the

market. Using this concept, we adopt the method proposed by Eizenberg (2014) to estimate an upper bound for fixed costs in our entry-game counterfactuals. Due to regulated entry and price-cost margins, we are unable to identify the lower bounds for fixed costs. As a result, our counterfactuals assume the minimum upper bound estimates for all entrants. However, we allow for variation between rural and urban pharmacies by assigning them different fixed costs, reflecting differences in real estate prices and pharmacists' opportunity costs.

Our entry game is based on the algorithm developed by Seim and Waldfogel (2013) and Verboven and Yontcheva (2024). In this model, there is no vertical differentiation between entrants, so they compete solely based on location. We also assume that all entrants are myopic, meaning they do not consider the actions of future players when making their entry decisions. Although these assumptions are restrictive, they are necessary to make the model computationally solvable. Solving the full model with forward-looking entrants or multiple control variables would be nearly impossible.

In the original algorithm, as used by Seim and Waldfogel (2013) and Verboven and Yontcheva (2024), players iteratively select the most profitable locations. However, in our application, we reverse this process: We start with entrants in all possible locations and sequentially remove those in the least profitable locations until entry is no longer profitable and no pharmacies want to exit the market. This approach significantly improves computational efficiency. Although both methods produce a market structure that satisfies the same conditions, they do not necessarily produce the same outcome. Additionally, neither approach guarantees that the resulting market structure is a Nash equilibrium or even unique.

Our counterfactual simulations indicate that deregulation would lead to a significant increase in the number of pharmacies, particularly in urban areas, with the total number of pharmacies increasing by 180%, resulting

in 2,276 pharmacies. This expansion would cause a significant increase in pharmaceutical sales by 200 million euros and increase the aggregate consumer surplus by 68 million euros due to shorter travel times and more pharmacy options. Furthermore, the change in consumer welfare is positive for 98% of the population. However, 2% of consumers would experience a decrease in welfare, mainly due to the loss of their local pharmacy.

Because the number of pharmacies increases relatively more than aggregate sales, the business-stealing effects dominates, leading to a decrease in aggregate industry profits as fixed costs rise and labor productivity declines. Together, the increase in consumer surplus and the decrease in industry profits highlight our key result: Existing entry restrictions primarily benefit the industry—or the incumbent pharmacists—at the expense of consumers. However, the overall increase in costs, including aggregate fixed costs, exceeds the gains in consumer welfare. Additionally, the rise of smaller pharmacies post-deregulation would reduce labor productivity due to diminished economies of scale. This suggests that deregulation may lead to excessive entry from a total welfare perspective.

It is important to note that our free entry counterfactual does not account for potential efficiency gains from pharmacy retail chains. In actual markets, horizontal integration enables firms to internalize part of the business-stealing effects and reduce costs through mergers. For this reason, policymakers should avoid prohibiting the formation of pharmacy chains or horizontal integration in the event of entry deregulation.

We find that deregulation, without corresponding price controls, could reduce overall welfare. This result emphasizes the need to carefully consider both the benefits and costs of market deregulation in sectors with significant entry barriers. Empirical studies by Berry and Waldfogel (1999) and Hsieh and Moretti (2003) document welfare distortions arising from unrestricted entry. Furthermore, Schaumans and Verboven (2008) and

Verboven and Yontcheva (2024) investigate entry restrictions in similarly regulated markets, revealing that such barriers often benefit producers more than consumers. Our findings also align with Winston (1993, 1998), who argues that deregulation can enhance efficiency and consumer welfare. Our contribution to this body of literature is the estimation of the distributional effects across different consumer groups. Most importantly, our main methodological contribution is a significantly faster entry algorithm that produces a market structure that satisfies the same conditions as the Seim and Waldfogel (2013) algorithm.

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Essay I

Kortelainen, Mika and Markkanen, Jaakko and Siikanen, Markku and Toivanen, Otto. The Effects of Price Regulation on Pharmaceutical Expenditure and Availability. *Unpublished manuscript*.

The Effects of Price Regulation on Pharmaceutical Expenditure and Availability*

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Abstract

Quasi-experimental evidence on the effects of price regulation policies and changes in incentives for producers, wholesalers, physicians, pharmacists and patients, on pharmaceutical expenditure per dose and on drug availability is scant. We analyze widely used price regulation policies, construct treatment and control groups by matching data across Nordic countries by active ingredients and by employing difference-in-differences methods on market-level observations. Regimes that increase patient price-sensitivity or impose price decreases over time reduce expenditure the most. We find no adverse effects on pharmaceutical availability and non-existent or positive quantity effects.

Keywords: *pharmaceutical expenditure, pharmaceutical pricing, generic competition, reference pricing, regulation, pharmaceutical availability*
JEL-Classification: *I11, I18, H51, L51, L65, C23*

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1 Introduction

Spending on pharmaceuticals continues to grow globally (IQVIA 2021), putting pressure on insurance premia and public finances. Countries with public health insurance have experimented with different regulatory regimes affecting the incentives of participants in the decision-making process—producers, wholesalers, physicians, pharmacists and patients—to decrease pharmaceutical expenditure per dose.[1] The challenge with measures that directly increase competition or induce higher price-sensitivity among patients is that the availability of drugs may be compromised. Despite the widespread use of these types of policies, credible causal evidence on their impact on pharmaceutical expenditure and availability remains scarce. This paper seeks to address this gap in the existing literature.

We study pharmaceutical markets with generic competition in four Nordic countries that have implemented different Reference Pricing (RP) and Generic Substitution (GS) policies—Denmark, Finland, Norway and Sweden. Generic markets are important: One third of pharmacy sales in the countries we study are in such markets, and in the US, more than 90% of prescriptions are for generic drugs (US Food and Drug Administration 2022).[2] GS refers to changing the product from the prescribed one keeping the active ingredient ("molecule"), strength, package size and the dosage form the same, whereas RP policies dictate product-level reimbursement. We examine the impacts of regulatory changes on expenditure per dose, pharmaceutical availability, prices and quantities.

The Nordic countries provide an excellent research setting for us: First, they offer generous public insurance against pharmaceutical expenditure and thereby muted incentives to compete in the supply chain and for consumers to choose

1. Similar initiatives have appeared in the US where health insurance is largely private: See e.g., Trump administration's Executive Order 13948 of September 13, 2020 on external reference pricing and Biden administration's Executive Order 14036 of July 9, 2021 on promoting generic and biosimilar competition.

2. Markets where the patent protection of the original drug has lapsed are generic, allowing competitors to enter with products using the same molecule. Other markets are monopolies with patent protection, possibly facing parallel imports. Cockburn, Lanjouw, and Schankerman (2016) and Kyle (2007) study the effect of patent protection and regulation on introduction of new drugs, Kyle (2022) provides a recent overview of innovation incentives for pharmaceuticals and Morton and Kyle (2012) cover the economics of pharmaceutical markets in general and that of generic entry in particular.

cheaper products. Second, Nordic countries have experienced large increases in pharmaceutical expenditure. Third, as a reaction, they have adopted several variants of Internal Reference Pricing (IRP) and External Reference Pricing (ERP) policies during the 2000s, moving gradually to stricter regimes with greater financial incentives for patients, in particular. The main objective of these policies is to reduce pharmaceutical expenditure through (generic) competition and increased consumer price sensitivity. We study six major reforms; the incentives of all participants but physicians are affected by at least one of these reforms. Fourth, these Nordic countries are as homogeneous as groups of countries come, making them appealing controls for each other.[3]

Our first contribution provides a comprehensive review of how incentives are impacted by various reforms and evaluation of the effects of these reforms, whereas the existing literature has examined individual reforms. Equally importantly, our main outcome variable is expenditure per dose instead of price, as commonly used in the literature. Expenditure per dose captures not only the reform's effect on prices, but also its impact on product choices.

Second, much of the literature has overlooked the Stable Unit Treatment Value Assumption (SUTVA) assumption, which states that each unit's potential outcome should be unaffected by the treatment status of any other units, both across and within control and treatment groups (Imbens and Rubin 2015, p. 10). In studying individual product prices within a single country—the typical approach in the literature—SUTVA implies the unrealistic assumption that the price of a product is unaffected by substitute prices. This exclusion of equilibrium effects contradicts both theoretical models and empirical evidence.[4] A common misconception is that SUTVA, if mentioned at all, concerns only spillovers between control and treatment groups. We address SUTVA by using control groups from other countries that are arguably unaffected by considered reforms and by focusing on market-level outcomes.

Third, unlike previous research, we also study the impact of price regulation on pharmaceutical availability. While reducing expenditure may be a success, it

3. We provide evidence on their similarity vis-á-vis pharmaceutical markets and demand in Online Appendix Section B.1 and on the objectives of price regulation in Section B.3.2.

4. Alves, Burton, and Fleitas (2024) analyze biases arising from SUTVA violations, while Minton and Mulligan (2024) examine SUTVA issues in industry studies through price theory.

could also result in product withdrawals and firm exits, potentially undercutting regulatory objectives. We account for the introduction of new (i.e., entry) and withdrawal (i.e., exit) of existing products and how these relate to the changes in the regulatory regime.

These contributions are possible due to our research design: Our control groups consist of the same markets in a neighboring country of similar appearance.[5] Our research design provides advantages in both data quantity and the quality of the match between treatment and control groups compared to the common approach of using different active ingredients or staggered entry times within the same country. It also allows us to use market-level outcomes to avoid the most severe SUTVA violations while maintaining reasonably large estimation samples.

Our first main finding is that incentives targeted by reforms are effective, with stronger incentives leading to sizeable reductions in expenditure. Furthermore, our results indicate that policies targeting both consumers and firms have the greatest impact on reducing expenditure. Both consumers (the Finnish 2003 Voluntary Generic Substitution (VGS) → GS and 2009 GS → IRP reforms) and producers (the Danish 2000 and 2005 reforms shifting from IRP to ERP and back) react to relatively small changes in incentives, leading to a decrease in expenditures. Expenditure effects are stronger when the incentives of all groups, except physicians, are affected, as in the Norwegian 2009 GS → Step-Price (SP) reform, which imposed large regulator-mandated price decreases following generic entry. The strongest effects are brought about by the 2009 Swedish Product of the Month Auction (Auction-IRP) reform, which introduced strong auction-type incentives for producers by effectively guaranteeing a large market share for the cheapest product within a substitution group, achieving this in part by giving consumers strong incentives to choose the cheapest product. This reform is an example of how physician incentives are left untouched, although they are key decision-makers: Through prescription, Swedish physicians decide the substitution group within which consumers can choose products. Going from the laxest regime (Finnish pre-2003 VGS) to the strictest (Swedish post-2009 Auction-IRP) we find

5. Tazhitdinova and Vazquez-Bare (2023) study issues arising when the control group operates under a different baseline policy than the treatment group. While this applies in some of our analyses, it does not affect others. When the treatment effect remains stable over time, as observed in our case, baseline policy differences are not problematic.

an overall decrease in expenditure of $\approx 44\%$. The very small estimated quantity effects suggest highly inelastic demand, meaning that expenditure savings translate roughly to increases in consumer surplus.[6]

Three channels could generate these expenditure effects: Quantity decreases, price reductions, and/or substitution towards cheaper alternatives. We find no evidence of quantity effects, but prices are affected by the Danish reforms and, to a greater extent, the Swedish Auction-IRP reform. Price effects are significantly smaller than expenditure effects in the Norwegian and Swedish reforms generating the largest expenditure effects. The price change induced by a reform, being the change in average prices, ignores changes in product choice induced by the reform, while the change in expenditure takes such changes into account.

The Swedish 2009 IRP $\rightarrow$ Auction-IRP reform demonstrates the likely mechanism: It introduced a combination of a procurement auction and strong consumer incentives. In Auction-IRP, the vast majority of consumers need to buy the cheapest product to receive reimbursement, but some may be prescribed a more expensive product. While all other products are priced higher than the product-of-the-month, some firms may have an incentive to price their product high to cream-skim locked-in customers. The average posted price in a market may thus remain relatively high, while the lowest price—the price of the product that most patients are dispensed and which therefore dominates expenditure—can be very low. A substantial part of the savings seem to come from customers reallocating their purchases. To illustrate, assuming that all prices changed by the same percentage, the share of expenditure savings due to reallocation of demand is approximated by $1 - ATT_{price}/ATT_{expenditure}$, yielding 57% in the Swedish case.

Our second main finding is that none of the reforms had any adverse effects on pharmaceutical availability. The ATT estimates are small in magnitude and mostly relatively precisely estimated. This result suggests that regulators should not be too worried about product availability when providing participants with stronger incentives. One explanation for the lack of adverse availability results is that in many cases expenditure decreases are driven by demand reallocation instead of

6. A few caveats should be kept in mind in interpreting this approximation: First, no account is taken of the shadow cost of public funds, though a large share of expenditure is covered by the public sector. Second, we have not estimated price elasticities but infer the steepness of the demand function(s) from our Average Treatment Effect on the Treated (ATT)s on quantity.

large price decreases. This could mean that modest price decreases were too low to induce shortages. A caveat to keep in mind is that our post-reform periods are relatively short, and hence we cannot rule out availability effects in the longer run and our existing results do not rule out local or short-term availability challenges.

Our paper contributes to three strands of literature, foremost the literature on the effects of pharmaceutical price regulation on expenditure and prices. The existing literature has mostly shied away from studying the effect of price regulation directly on expenditure. Researchers have either used package- or product-level data on posted prices as a proxy for pharmaceutical expenditure (e.g. Danzon and Chao 2000; Pavcnik 2002; Brekke, Grasdal, and Holmås 2009; Brekke, Holmas, and Straume 2011) or a structural approach to evaluate the impact of price regulation on competition, welfare, and savings in public expenditure (Dubois and Lasio 2018; Maini and Pammolli 2023; Dubois, Gandhi, and Vasserman 2022).[7] The first literature has revealed interesting dynamic competitive effects due to policy changes and has shown how these effects are affected by the strategic interaction between brand-name and generic firms as a response to the price sensitivity induced by reference pricing. The only quasi-experimental analysis of the effect of a regulatory reform on pharmaceutical expenditure that we are aware of is Brekke, Holmas, and Straume (2011).[8] We focus on the aggregate effects on pharmaceutical expenditure per dose at the market level, which is arguably the most interesting outcome from a policy perspective. Our findings suggest limitations in the first approach, while our methods provide a complementary perspective to the second body of literature.

Dubois and Lasio (2018) is an important precursor in using multi-country data. While their structural approach has the potential to allow for an evaluation of the welfare effects of regulation, they acknowledge that the complicated process of choosing a particular drug involving many parties complicates the interpretation of welfare measures. We shy away from structural modeling because of the scale of the challenge: Depending on the level of detail adopted, our data contain 7–11 different regulatory regimes in need of modeling.

7. Feng, Hwang, and Maini (2023) study the effects of most favored customer clauses in Medicaid and find that removing them would decrease expenditure by 3.5%.

8. Using within-country data on 24 Anatomical Therapeutic Chemical classification system (ATC) level 5 groups, 8 of which were treated, they found that the introduction of RP reduced expenditure in Norway by 30%.

The second literature is concerned with demand reallocation by steering patients to choose generic and less expensive drugs. Several studies have investigated the effects of Medicare Part D and its incentive structures on drug prices and pharmaceutical expenditure. Duggan and Scott Morton (2010) demonstrate that private insurers have been able to decrease prices for previously uninsured with incentive-based formularies. Einav, Finkelstein, and Polyakova (2018) show complementary evidence that private insurance plans in Medicare Part D systematically set higher out-of-pocket (OOP) prices (coinsurance rates) for drugs with more elastic demand. Starc and Swanson (2021) find that Medicare Part D plans can save money by utilizing preferred pharmacy networks, but that the savings are reduced by enrollees' low price sensitivity.[9]

A source of criticism for pharmaceutical price regulation are possible adverse effects on pharmaceutical availability and innovation (e.g., Lakdawalla 2018). The recent literature has focused on pharmaceutical shortages and documented that both consolidation and price competition can increase them (Yurukoglu, Liebman, and Ridley 2017; Stomberg 2016; Dubois, Majewska, and Reig 2023). Yet, we are not aware of any papers that study the direct effect of price regulation on pharmaceutical availability. While innovation is likely a secondary concern in this paper, regulatory effects on innovation may be a significant issue in other contexts (Acemoglu and Linn 2004; Yin 2008; Ornaghi 2009; Dubois, Mouzon, Scott-Morton, and Seabright 2015; Frech, Pauly, Comanor, and Martinez 2023). First, the markets we study are small, representing only 1% of the global pharmaceutical market. Second, these markets are off-patent and thus far in the future from the perspective of those deciding R&D investments. A back-of-the-envelope calculation using a 0.95 discount rate suggests that, keeping annual profits constant, the Net Present Value (NPV) of the profit in year 11 of patent life is 5.95% and in year 15 0.21% of the first year profit.

Following this introduction, we present the relevant institutions and regulatory regimes in Section 2 where we also discuss theoretical predictions regarding price and expenditure changes. We introduce the data, motivate our choice of control countries and explain our procedure of matching markets in Section 3. We present

9. Several papers have studied the same issue regarding other health treatments, e.g. Einav, Finkelstein, and Williams (2016).

our Difference-in-Differences (DID) approach and discuss the timing of reforms and the choice of estimation periods in Section 4. Section 5 is devoted to the presentation and discussion of the results. We discuss most of our robustness analyses along the way, but conclude Section 5 by analyzing whether our market definition is too narrow. We offer conclusions in Section 6.

2 Institutions and Regulatory Regimes

All Nordic countries have a universal single-payer insurance system, aka the Beveridge model, in which all citizens receive insurance coverage through the state. The system is financed by taxes, and enrollment is automatic and free. Publicly provided care is offered at very low or non-existent prices, and patients do not face deductibles or premiums in public services. There are some exceptions to this rule, prescription drugs being a notable one. Pharmaceuticals are reimbursed by the public sector in all Nordic countries (see Online Appendix B.1 for details). Although there are differences both across countries and across time, the reimbursements are generous and individuals' annual drug expenditures are capped, the highest cap being Finland's 610 euros (see Table B.2 in Online Appendix B.1). The universal single-payer system has made the demand for pharmaceuticals very inelastic, motivating the use of price regulation to control prices.

A key regulatory tool are price cap regulations that exist in all Nordic countries. These caps ensure that the price of a given product does not exceed a predefined level and are typically applied during the on-patent period, negotiated between manufacturers and the government. Price caps serve as the legal basis for negotiations between pharmaceutical manufacturers and public health insurance systems. Unlike consumer choice regulations such as reference pricing, price cap regulation targets monopoly markets and depends on the bargaining power of public insurers. Without strong bargaining power, manufacturers may choose not to enter the market. These caps can also exist during generic competition (such as the Norwegian 2005 SP reform) together with RP policies. The Nordic countries implement price caps for generic markets using different approaches: Finland and Sweden set caps using price information from the monopoly period, Norway uses price information from other countries, and Denmark relies on industry self-regulation and price

freeze agreements between the regulator and the industry.

In contrast to price cap regulation, we focus on consumer choice reforms implemented in generic pharmaceutical markets. These reforms aim to alter the incentives of consumers and, to a lesser extent, pharmaceutical firms. From the perspective of policymakers, the motivation for such reforms is straightforward: After patent expiration and loss of exclusivity, governments can leverage competition to design consumer choice policies that increase price elasticity. RP policies rely on the existence of generic competition, even though they primarily target consumer incentives. This makes them distinct from price caps and bargaining strategies, which at most benefit from therapeutic competition between drugs with different active ingredients. We define the various consumer choice policy regimes that influence wholesale pharmaceutical prices in our data and describe the regimes and reforms implemented in different countries over time.

2.1 Regulatory Regimes

In official use, different regulatory regimes and consumer choice reforms can share the same name in different countries. We use the following definitions and acronyms:

Definition 2.1. Voluntary Generic Substitution (VGS). Substitution with a cheaper interchangeable product is possible, but requires a decision by the prescribing physician.

Definition 2.2. Generic Substitution (GS). Substitution with a cheaper interchangeable product must be offered to the consumer in the pharmacy. Substitution can be done in the pharmacy without the need to consult the prescribing physician. The medicines authority determines which products are substitutable.

Definition 2.3. Reference Pricing (RP). The consumer has to pay out of pocket the price difference between the price of the prescribed product and the price of the reference product if she declines generic substitution. RP (also called "margin pricing"; Einav, Finkelstein, and Williams 2016) is determined within a basket of same-molecule drugs. RP can be implemented in a number of ways which fall under the following two main approaches:

Definition 2.4. External Reference Pricing (ERP). The reference price is determined as a function of prices in both foreign and domestic markets.

Definition 2.5. Internal Reference Pricing (IRP). The reference price is determined as a function of domestic prices only.[10]

Definition 2.6. Step-Price (SP). A RP system in which the government enforces gradual, predetermined decreases to the maximum reimbursed price after generic entry.

Definition 2.7. Product of the Month Auction (Auction-IRP). An internal reference price system where reimbursement is only granted for the prescribed product and the winner of a monthly auction. The lowest bid in the auction determines the reference price. Customers pay 100% out of pocket in case they choose any other product than the product of the month or the prescribed product. If the prescribed product is not the product of the month and the customer chooses it, she pays the out of pocket price she would have paid for the product of the month, and the whole price difference between the prescribed product and the the product of the month.

We define a market as an active ingredient in a given country and month, i.e., at the ATC5 level. The primary justification for this is that the price regulations we examine operate at the ATC5 level: All the reforms allow consumers to make choices within a single active ingredient (market) but not across different active ingredients (markets).[11] However, in some cases, a physician can choose the prescription among different active ingredients. For example, simvastatin and atorvastatin, two different active ingredients, are both used to treat high cholesterol. We test for spillovers between different ATC5 classes within the same ATC4 class in subsection 5.5 and find no evidence of such spillovers.

Regulatory policies often consist of a combination of GS and some form of RP, but sometimes only one or the other is used. For example, in the early 2000s,

10. Our definitions of reference pricing contain generic substitution, i.e., in what follows IRP and ERP should be understood as GS+IRP and GS+ERP.

11. The ATC system classifies active ingredients according to their therapeutic, pharmacological, and chemical properties. Pharmaceutical products that belong to the same ATC5 category share the same active ingredients and are considered equivalent for the treatment of the same disease.

Finland and Norway adopted GS systems without RP, meaning that there were no financial incentives for customers. On the other hand, the Swedish GS system has always been coupled with RP. Even when not explicitly stated—as in SP—these regulations are complemented by a maximum price regulation of varying degrees of severity in all other Nordic countries but Denmark.

Some regulations come from European Union (EU) law, which establishes the European single market. For example, parallel trade—the importation of pharmaceuticals between Member States irrespective of patent status—is protected. Other types of pharmaceutical regulation, such as public reimbursement, price regulation, and the distribution of pharmaceuticals are left to individual Member States. However, EU can place some restrictions on national regulators.[12]

2.2 Summary of Reforms

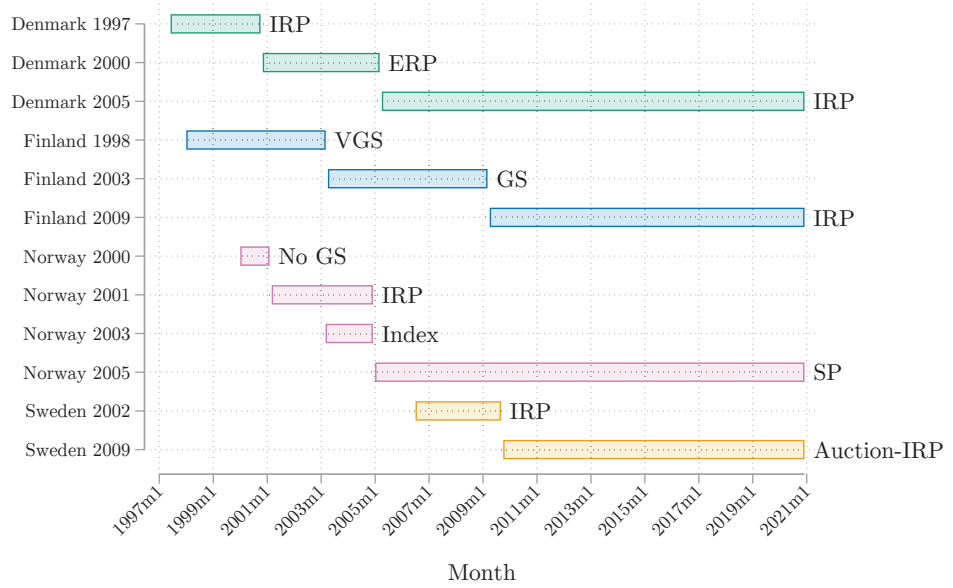
We now summarize the relevant regulatory regimes in place in the four countries during our observation period and explain the regime changes studied. All studied reforms were motivated by a need to reduce pharmaceutical expenditure (see Online Appendix Sections B.3.2–B.3.6 for more information).

Figure 1 shows the regimes in place and the reforms (= regime changes) implemented during our observation period, organized by country and chronologically. We exclude two Norwegian reforms from our analysis. The Norwegian 2001 reform that combines pharmacy market liberalization and GS reform is excluded because we cannot separately identify their effects on the outcomes. The Norwegian 2003 reform introducing the so-called Index Pricing is excluded as it directly influenced only eight markets (active ingredients). Thus, a market-level analysis becomes difficult, because given the timing of reforms in the other countries, we cannot form a good control group. We analyze the 2005 Norwegian reform using data on pharmaceuticals not included in the Index Price regulation.[13]

12. The Treaty on European Union, Articles 34 and 36, provides the legal basis for parallel imports: See the precedent of the Court of Justice of the European Union in Pfizer Inc. v Eurim-Pharm GmbH. (1981). An example of EU restrictions on national regulation is the maximum processing time for reimbursement decisions: 180 days for new pricing and reimbursement decisions, 90 days for review of an application to increase prices. See Directive 89/105/EEC.

13. The Index Price system was an IRP system where the reference price was calculated as a sales-weighted average of producer prices by each reference price group; for a review of the Index

Figure 1: Timeline of reforms



Notes: Abbreviations used: IRP, ERP, VGS, GS, SP, VGS, Auction-IRP

The examined reforms are presented in Table 1. The table shows the treatment country, the regulatory regimes before and after the reform, the country providing control group markets, and the regulatory regime in the control country. We discuss the choice of control countries in Section 3.2.

2.3 Reform-induced Incentive Changes

Table 2 identifies the market participants whose incentives were directly targeted by the reforms. Our analysis focuses on these groups. The top section of Table 2 illustrates the vertical chain of the pharmaceutical market in the Nordic countries. Producers manufacture drugs, physicians prescribe them, pharmacists dispense

Price system, see Brekke, Grasdal, and Holmås (2009) and Brekke, Holmas, and Straume (2011). We do not analyze the Index Price reform, since the small number of treated markets (8) does not leave room us to study market level outcomes.

Table 1: Treatment and Control Countries

Year	Treatment Country	Reform	Control Country	Control Regime
2000	Denmark	IRP → ERP	Finland	VGS
2005	Denmark	ERP → IRP	Finland	GS
2003	Finland	VGS → GS	Denmark	ERP
2009	Finland	GS → IRP	Norway	SP
2005	Norway	GS → SP	Finland	GS
2009	Sweden	IRP → Auction-IRP	Denmark	IRP

Notes: IRP = Internal reference pricing, ERP = External reference pricing, VGS = Voluntary Generic substitution, GS = Generic substitution, SP = Step-price, Auction-IRP = Product of the Month Auction.

them, and the chain concludes when the consumer makes a purchase decision at a pharmacy. Producers earn a markup embedded in the wholesale price, while wholesaler margins, to our understanding are a small percentage of the wholesale price. Physician income is not related to what products they prescribe, nor do they have specific budgets.[14] While general guidance on treatments exist, to our knowledge physicians do not get systematic individual guidance related to prices. In all but one of the regimes we study, the Norwegian SP being the exception, pharmacists earn a markup that is defined as a percentage of the wholesale price. They thus would have an incentive to encourage consumers to choose a more expensive product. As explained above, consumers out-of-pocket expenditure varies and after a threshold, goes to zero.

A key feature of the Nordic market is that all market participants are subject to some form of regulation. The studied reforms are designed to directly impact multiple participants. Additionally, most reforms have indirect effects, as changes in firm and/or consumer incentives prompt all participants to re-optimize their decisions. Incentives interact with one another; e.g., a policy targeting consumer incentives affects prices, primarily through a change in the elasticity of demand rather than a change in firms' conduct. Conversely, a policy targeting firms' conduct

14. The only exception is Sweden, where physicians received monetary incentives for prescribing generic products. See Online Appendix Subsection B.1 for additional details.

Table 2: Cost Containment Incentive Changes

Producer → Wholesaler → Physician → Pharmacy → Consumer

	ERP 2000	**IRP 2005**	**GS 2003**	**RP 2009**	**SP 2005**	**Auction-IRP 2009**
	Denmark	**Denmark**	**Finland**	**Finland**	**Norway**	**Sweden**
Producer	⊕	⊖	0	0	0	⊕⊕
Wholesaler	0	0	0	0	⊕	0
Pharmacy	0	0	0	0	⊕	0
Physician	0	0	0	0	0	0
Consumer	0	0	⊕	⊕⊕	⊕⊕	⊕⊕⊕

Notes: This table presents the incentive changes between the previous and introduced regulatory regimes. The timeline shows the decision-making chain. Changes in incentives are indicated by ⊕, ⊖ and 0. ⊕ signifies an increase, ⊖ a decrease in incentives. Major changes are represented by three characters (for example, ⊕⊕⊕), moderate changes by two (e.g., ⊕⊕), and small changes by one (e.g., ⊕). A zero (0) indicates no change in incentives.

can influence consumer incentives by altering relative prices.

In Table 2, rows denote market participants and columns denote each studied reform. Incentive changes are indicated using ⊕, ⊖, or 0. ⊕ signifies an increase in incentives, while a ⊖ indicates a decrease in incentives. Major changes are represented by three characters (for example, ⊕⊕⊕), moderate changes by two characters (e.g., ⊕⊕), and small changes by one character (e.g., ⊕). A zero (0) indicates no change in incentives.

The Danish 2000 IRP → ERP reform (Column 1 in Table 2) required firms to provide price information from other EU countries to the regulator. This change in incentives targeted firms operating in multiple European countries but had no effect on firms operating only in Denmark; consumer incentives remained unchanged. We classify the change in firm incentives as small. The Danish 2005 ERP → IRP reform (Column 2 in Table 2) reversed the cost-containment incentives introduced by the previous reform, resulting in a small decrease in firm incentives. ERP may affect producer incentives in other countries and may thus result in strategic behavior (see Maini and Pammolli 2023). The Nordic countries are seldom if ever "pivotal" for each other in ERP schemes given that countries with lower price levels are included

in ERP and it is therefore unlikely that ERP results in such strategic behavior in the control country.[15] Our empirical strategy allows us to capture the effects of such strategic behavior on the outcome variables in the treatment country.

The third column in Table 2 denotes the Finnish 2003 VGS → GS reform. This reform directly targeted consumer choices by expanding the consumer choice set from the prescribed product to products that are identical (substitutable) with the prescribed product. At the same time, pharmacies provided information to consumers on the existence of substitutable products. We label the change in consumer incentives as small because, although the reform provided consumers more price information, it left their level of reimbursement nearly unchanged, resulting in minimal financial incentive to choose cheaper products. The Finnish 2009 GS → IRP reform (Column 4 in Table 2) provided financial incentives to buy cheaper alternatives through the reimbursement system by directly changing consumers' OOP costs. We therefore categorize consumer incentives as moderate.

The Norwegian 2005 IRP → SP (Table 2 Column 5) reform is the only reform that directly targeted parts of the vertical market structure and consumers. The possibility of vertical integration between wholesalers and pharmacies increased the incentive to sell cheaper products. We label the consumer incentive change as a moderate increase, and the wholesaler and pharmacy incentive changes as small increases. The last column of Table 2 presents the Swedish 2009 IRP → Auction-IRP reform, which directly targeted both producers and consumers. The change in consumer incentives is classified as significant because the system restricted reimbursement to only the winning product of the auction and the original prescription. Similarly, producer conduct changed as firms were required to submit binding bids in the auction. The Swedish Auction-IRP system thus resembles a public procurement system at the national level. This procurement analogy could, in principle, also apply to other RP policies, as national reimbursement systems with periodically set RPs effectively use the Reference Pricing System (RPS) to procure reimbursable prices through price competition.

15. Our analysis focuses on time periods after the loss of exclusivity and decreases the likelihood that ERP would generate spillovers.

2.4 Price vs. Expenditure Effects

How might the price and expenditure effects of reforms differ? We use the model of Brekke, Holmas, and Straume (2011) to provide insights on the price and expenditure effects of some of the reforms. They study a model of vertical product differentiation featuring copayments, a preferred branded and a generic producer as well as an outside good. A binding price cap reduces both prices compared to an equilibrium with no cap, but that of the branded drug more. The market share of the branded drug increases relative to that of the generic one. With ERP, the price of the branded product decreases and that of the generic increases, with market shares adjusting accordingly. The sign of the change in average prices and expenditure depends on model parameters. IRP leads to both prices decreasing, with the branded price decreasing more in absolute terms. Despite this, the generic market share increases relative to that of the branded drug.

We have collected the predictions regarding price and expenditure effects into Table 3. Although the introduction of a price cap decreases both prices, the effect on expenditure on dose is unclear as the (inside) market share of the more expensive branded product increases. ERP leads to the two prices developing in opposite directions and hence the development both of average prices and expenditure is an empirical matter. In contrast, the model of Brekke, Holmas, and Straume (2011) delivers clear predictions regarding the introduction of IRP: Both prices decrease and the market share of the generic product increases relative to that of the branded. Because of this shift in demand towards the cheaper product, expenditure decreases by more than prices. More generally, the lesson is that there is little reason to think that price and expenditure effects would be identical.

3 Data and Matching

3.1 Sales and Reform Data

We use data from four different data providers on monthly revenues and quantities of drugs purchased by community pharmacies. Our data covers the Nordic countries, excluding Iceland. The data sets contain information on product characteristics and

Table 3: Price vs. Expenditure Effects

Regime	Δp	Δexp	$\|\Delta p\|$ - $\|\Delta exp\|$
Price cap	< 0	?	?
ERP	?	?	?
IRP	< 0	< 0	< 0

Notes: Δp is the difference in arithmetic average price moving from a regime of no price cap, ERP or IRP to the regime indicated in column one. Δexp is the similarly defined change in expenditure per dose. "?" indicates that the value depends on parameter values.

the sales value and volume of each pharmaceutical package sold in the respective country. The sales values are defined in pharmacy purchase (=wholesale) prices and volumes in Defined Daily Dosages (DDD) for each respective active ingredient according to the ATC. We supplement our sales data with rich regulatory information obtained from market regulators and legislation and list the data sources for each country and reform in Appendix Section A.1 Table A.1. We use wholesale prices for two reasons:[16] First, the regulations target wholesale prices. Second, the retail price in each country is determined using a mechanical formula based on the wholesale price. The only exception is the Norwegian 2005 SP regime, where only an upper bound for the retail price is based on the wholesale price. We show the Nordic price formulae in Online Appendix Table B.3.

To account for potential equilibrium (SUTVA) effects, we depart from the literature by aggregating our outcome variables to the market level, specifically the active ingredient-country-month level. We construct the outcome variables from products with a DDD to measure quantities across different package sizes and product strengths. Our main outcomes are (logarithm of) average Expenditure per Dose and availability, measured by the Number of Product Names. We construct our expenditure variable as follows:

$$exp_{mt} = \frac{\sum_{i \in M_t} p_{it} q_{it}}{\sum_{i \in M_t} q_{it}} \tag{1}$$

16. In contrast to the U.S. (e.g. Alpert, Duggan, and Hellerstein 2013), in the countries we study, wholesale prices are the prices pharmacies actually pay.

p_{it} is the price per dose and q_{it} the number of sold daily doses of package i and M_t the set of products available in market m, all in period t. Expenditure can be thus seen as the quantity-weighted average price.[17] Auxiliary outcome variables are the arithmetic average Price per Dose $p_{mt} = (\sum_{i \in M_t} p_{it})/N_{mt}$ and quantity $q_{mt} = \sum_{i \in M_t} q_{it}$ where N_{mt} is the number of packages in market m in period t. Prices and sales are measured in nominal national currencies because the price regulations work with nominal prices.[18] As the sample periods are short (2–4 years) and inflation low, differential inflation trajectories should not cause bias.

3.2 Choice of Control Countries

To choose a control country, we identify countries where no major regulatory changes occur in the years right before and after a given reform in the treatment country. Figure 1 reveals that one or two countries are available as control countries for each reform. Two control countries are available for the Finnish 2009 GS → IRP and the Swedish 2009 IRP → Auction-IRP reforms. We order the discussion of control country choice starting with reforms without changes in customer incentives, moving then to reforms with small, modest and finally major changes.

No changes in customer incentives: The Danish 2000 IRP → ERP and 2005 ERP → IRP reforms. For the Danish 2000 IRP → ERP reform Finland is the control country. The Finnish regime at the time was VGS. We use Finland as the control country also when we study the Danish 2005 ERP → IRP reform that reverses the previous reform.

Small changes in customer incentives: The Finnish 2003 VGS → GS reform. We use Denmark, using ERP at that time, as the control country for the Finnish 2003 VGS → GS reform. Using Denmark and Finland as control countries for each other is less ominous than it sounds and is supported by the following facts: First, our different estimation samples consist neither of the same markets because the number of markets with generic competition increases over time nor,

17. The numerator in equation (1) is the same as in Laspeyres and Paarsche price indices.

18. Sales data from Finland is in euros as the switch from FIM to EUR occurs during our sample (2002). We do not convert prices to the same currency because of exchange rate shocks. Exchange rate shocks are problematic with Swedish and Norwegian data because these currencies are not tied to the euro like the Danish krone. A visual inspection showed that this is a real concern. We show in Online Appendix B.4 how exchange rates evolve within our sample periods.

due to generic entry, of exactly the same products: The overlap in products is usually less than 20% and always less than 30% (see Table A.3 in Appendix Section A.2). Second, the overlap between the different analyses in the time dimension is minor. Third, as demonstrated below, the treatment effects of the reforms stabilize quickly, implying that the time-varying event study estimates are within each others' confidence intervals. Fourth, we do not find worrying pre-trends.

Modest changes in customer incentives: The Norwegian 2005 IRP → SP and the Finnish 2009 GS → IRP reforms. Figure 1 reveals that the country with a stable regulatory regime in 2005 is Finland, where GS was in place. We discard 8 treated Norwegian markets due to the Index Price regulation implemented in 2003 in Norway because otherwise the pre-period market institutions would not be the same for all studied Norwegian markets. For the Finnish 2009 GS → IRP reform, we use Norway, using SP at the time, as the control country. Denmark is available as an alternative control country: Those results, reported in Online Appendix Section B.6, are in line with the main results.

Major changes in customer incentives: The Sweden 2009 IRP → Auction-IRP reform. We use Denmark as the control country in the main analysis and perform a robustness tests using Norway as well as both Denmark and Norway as alternative control countries (see Online Appendix Section B.6). The results using different control countries are in line with each other.

A common issue in the DID framework is the comparability of the treated and control units. We restrict the set of control countries to the Nordics to maintain comparability of countries. Our claim is that the Nordic countries are very comparable. We detail in Online Appendix Section B.1 the similarity of Nordic countries in the institutional set-up of pharmaceutical markets. The main demographic drivers of pharmaceutical demand follow the same trends. In Online Appendix Section B.1 we show how population size, income and years of life lost from mortality (YLL) evolve in the Nordics before and after of each studied reform. We find no significant changes in demographic trends.

Optimally, one would want to have a control country that had the same regulatory regime as the treatment country prior to adoption. This is possible for the Swedish 2009 IRP → Auction-IRP reform as Denmark has the same regime as Sweden has until the reform. We discuss in Subsection 4.1 the implications

of the control country regulatory regime on identification using concepts from Tazhitdinova and Vazquez-Bare (2023).

3.3 Sample Matching

Our empirical strategy is based on comparing the pharmaceutical retail markets of a country subject to a reform (treatment country) with identical retail markets in another Nordic country (control country) before and after each reform. We match the markets by active ingredient (i.e., ATC5 level). The matching process proceeds in four steps: i) We discard non-prescription pharmaceutical products (over-the-counter (OTC) products) and the hospital market[19] for pharmaceuticals; ii) we identify the markets that are affected by the reform in the treated country; iii) we find the same markets in the control country; and iv) we drop non-treated markets, treated markets without a match, and matched markets where generic competition starts during the pre-period. Our estimation samples thus include different products and package sizes in the treatment and control markets. Product-level matching is, for two reasons, not a good idea: First, as we show in Appendix Table A.3, only 16%–28% of the treatment country packages can be found in the control country. Second, a package-level analysis would introduce SUTVA concerns and preclude our main objective, an analysis of changes in expenditure.

The decision to exclude hospital sales warrants a more detailed discussion. Pharmaceuticals used in inpatient care (hospital market) are excluded because centralized competitive bidding is used in all Nordic countries in public hospitals and our data do not contain tendered hospital prices. The share of pharmaceuticals distributed through hospitals affects the coverage of our analysis. The share of pharmacy sales is close to or above 80% in all other countries but Denmark where pharmacy sales decrease from circa 70% in the early 2000s to somewhat less than 50% by 2012 (see Online Appendix Figure A.1).

Table 4 shows how the estimation samples cover the pharmaceutical retail market. In Panel A, we describe how our matching process progresses from the

19. We share this data restriction with many of the published papers (Brekke, Holmas, and Straume 2011; Brekke, Grasdal, and Holmås 2009). See Allende, Atal, Carril, Cuesta, and González-Lira (2024) for a recent analysis of centralized pharmaceutical procurement similar to procurement by Nordic hospital districts.

Table 4: Matching Descriptive Statistics

	Generic Markets (1)	Treatment Markets (2)	Pre-Study Generic Competition (3)	Matched Markets (4)
Panel A: Number of ATC 5 markets				
Denmark 2000	110	68	64	59
Denmark 2005	150	114	100	91
Finland 2003	113	100	90	80
Finland 2009	132	132	123	105
Norway 2005	169	26	22	15
Sweden 2009	136	136	131	112
Panel B: Share of total pharmacy sales, %				
Denmark 2000	100.00	89.31	80.94	79.99
Denmark 2005	100.00	96.10	78.27	76.25
Finland 2003	100.00	96.05	80.03	75.69
Finland 2009	100.00	100.00	87.38	81.42
Norway 2005	100.00	42.36	27.78	12.59
Sweden 2009	100.00	100.00	93.83	88.24

Notes: All Markets = number of markets/market share of markets with generic competition during the observation period; Treatment Markets = number of markets/market share of markets where the new regulation is implemented; Pre-Study Competition = number of markets/market share of markets in which generic competition started before our observation period; Matched Markets = number of/market share of successfully matched markets. Outcome data source: DLI-MI (1999–2013), Farmastat (2004–2013), Fimea (1999–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013).

number of existing markets to the number of markets included in each estimation sample. Panel B shows the same information in terms of share of sales. The first column in Panel A gives the number of markets with generic competition in the treated country in the pre-period while the second column shows the number of treatment markets, which may be a subset of all markets with generic competition, depending on the coverage of regulation. For example (see Row 3), there were 113 (ATC5) markets with generic competition in Finland in 2003, 100 of which were affected by the VGS $\rightarrow$ GS reform. Column 3 reveals that we are left with

90 markets after discarding markets that experienced generic entry during the pre-period. Finally, after discarding markets that do not match with a counterpart in Denmark, we end up with 80 matched markets.

The difference between Columns 2 and 3 in Table 4 is informative about the exogeneity of reform timing concerning markets becoming competitive. If regulators design new regulation policies while taking into account how patents expire, we might see many markets becoming competitive during the reform pre-period (the difference between Columns 2 and 3 in Panel A) or that the market size of markets with generic entry during pre-period was substantial (the difference between Columns 2 and 3 in Panel B). The number and the size of markets that become competitive during the pre-period is not substantial.

In Panel B, Columns 2 and 3 show the sales share of the treated markets and markets with generic entry before the pre-period. The sales share of the treated markets varies from a low of 42% for the Norwegian GS → SP reform in 2005 to a high of 100% for the Danish ERP → IRP reform in 2005 and the Swedish IRP → Auction-IRP reform in 2009. The sales share of unmatched markets (the difference between Columns 3 and 4) is small.[20] The only exception is the Norwegian 2005 GS → SP reform, where the large decrease can be explained by the fact that we need to discard 8 markets that had been exposed to Index Price regulation in 2003.

4 Empirical Strategy

4.1 Research Design

The primary obstacle in identifying the effects of price regulation policies on product market outcomes based on single-country data is that regulations either cover almost all markets or target special markets. As a consequence, non-regulated products are typically different from regulated ones, making it difficult to form a plausible control group. The most prominent example is that price regulation policies related to GS can only be applied to markets with generic competition. Products that remain outside of consumer choice regulation are presumably in markets without competition. This can lead to comparisons in which the treatment

20. We display the number of observations for all estimation samples in Appendix Table A.2.

and control group products are at different stages of their product life cycle and come from different drug markets.

The second major challenge in evaluating the effects of (price) regulation in pharmaceutical markets using the DID approach is SUTVA, which rules out equilibrium effects both within and between the control and treatment groups. The existing quasi-experimental literature on pharmaceutical market price regulation reforms has measured outcomes at the package- or product-level, thereby imposing the implicit assumption that competing products' pricing decisions are independent.

To address these shortcomings, we base our empirical strategy on cross-country comparisons between two (or more) Nordic countries using market-level (ATC5) outcomes rather than within-country comparisons using product-level data. Similar estimation strategies have recently been utilized to investigate the effects of different taxation and welfare scheme policies in the Nordic countries (Agersnap, Jensen, and Kleven 2020; Benzarti, Carloni, Harju, and Kosonen 2020; Gruber, Jensen, and Kleven 2021).[21] Our approach allows comparisons between identical markets in different countries and makes SUTVA more plausible.

Our approach necessitates different assumptions than those invoked in the existing literature: We assume that there are no major pricing spillovers between countries that would change due to a reform, and that the trends in prices and sales in a given ATC5 market are comparable between the countries. Identification based on DID yields unbiased results if spillovers between studied countries are constant or non-existent over time. Only spillovers which immediately react to the timing of the reform would be problematic. We next discuss such international spillovers and why these likely have no first-order impact on our analysis.

Pricing spillovers are possible in the European pharmaceutical market, because many countries have incorporated the ERP system into their institutional setup, creating links between pricing in different countries (see Maini and Pammolli 2023). Furthermore, Nordic countries use the ERP system and other Nordic countries as a benchmark. We argue that pricing spillovers are not a problem in our setting because we study markets where generic competition has started before our sample

21. For example, Agersnap, Jensen, and Kleven (2020) compared non-EU immigration flows in Denmark and a synthetic control country constructed from the other Nordic countries before and after three welfare reforms in Denmark. We cannot construct a synthetic control group because of simultaneous reforms in other countries, for example, both in Finland and Sweden in 2009.

period. Also, it is unlikely that price differences between Nordic countries are large enough to generate spillovers through the ERP system. We also find that the overlap between products in the treatment and control countries is surprisingly small (See Appendix Section A.2 Table A.3). The danger of spillovers through the ERP therefore seems small as such spillovers require the existence of identical products in the compared country pairs.

We assume that there are no spillovers between ATC5 markets within a country. This is motivated by the fact that the price regulations are built on comparing products within an ATC5 group and hence consumer choice policies and substitution happen mostly within ATC5 markets. We test and find support for the validity of this assumption.

As we estimate DID models, we maintain an assumption on common trends: While the specific assumption is estimator-specific, the assumptions concern the (counterfactual) outcome-variable trends in the control and treatment markets. There are two main dangers to the common trends assumption in our setting where the control markets are from a different country: First, there could be country-market-specific demand or supply trends. We address these by matching the treated and control markets at the ATC5 level on the one hand, and using the relatively similar Nordic countries as each others' comparators on the other hand. The second challenge could arise if the control country has a different price regulation regime than the treatment country, which is the case for most of our settings. Tazhitdinova and Vazquez-Bare (2023) have documented that this setup can lead to biased estimates if the estimated treatment effect is not constant or non-immediate. We believe for two reasons that this issue does not influence our results. First, we find treatment effects that are stable over time.[22] Second, the Swedish 2009 IRP $\rightarrow$ Auction-IRP reform can be studied using a control group that has the same baseline treatment status (Denmark) and using a control group that has a different baseline status (Norway). We find very similar effects (See Section 5 and Online Appendix B.6), suggesting that at least in this case the control country having a different regulatory regime is not of material consequence. Finally, as will become clear in Appendix Subsection A.3, we do not find problematic pre-trends.

22. More specifically, the time-varying treatment estimates are within each others' confidence intervals.

4.2 Difference-in-Differences Estimators

Our empirical approach allows us to include market-country-specific fixed effects to account for level differences between markets and time-fixed effects to account for unobserved aggregate time trends and shocks.

We use either the standard Two-Way Fixed Effects (TWFE) estimator or the estimator proposed by Callaway and Sant'Anna (2021) which is robust to negative weighting issues arising from staggered treatment adoption and imposes a less strict parallel trends assumption. We use the former when there is no variation in treatment timing and the latter when the reform in question is implemented in a staggered fashion. Our TWFE estimation equation has the following form:

$$y_{itc} = \alpha_{ic} + \lambda_t + \sum_{\tau \neq -1} \beta_\tau \text{Reform}_{\tau c} + \epsilon_{itc} \tag{2}$$

where y_{itc} represents the (log of) monthly market level average expenditure per dose, the (log of) number of product names, the (log of) average price per dose or the (log of) quantity i in country c at time t. The subscript i denotes a market except when we analyze the price effects using package-level data to provide a comparison to the literature. α_{ic} denotes the country-observation unit-specific fixed effect. λ_t are time period fixed effects. $\text{Reform}_{\tau c}$ are relative time-to-treatment indicators which are set to 1 for treated markets if period t is τ periods from the start of treatment and is set to zero for all other periods for the treated markets, and all observations for the control markets. The coefficients of interest (β_τ) denote the average change between time τ and the last period before treatment in markets exposed to treatment, relative to control markets. When estimating the average effect of the reform, we replace $\sum_{\tau > -1} \beta_\tau \text{Reform}_\tau$ with $\beta_{att} \text{Reform}_\tau$ and set all β_τ, $\tau < -1$ to zero, β_{att} being the average impact of the reform on the treated units. ϵ_{itc} is the error term.

We cluster standard errors at the ATC5 level using a wild bootstrap procedure.[23] This clustering scheme allows dependencies within each market (ATC5) across

23. In our TWFE estimations, we use the estimator proposed by Correia (2016) to absorb the fixed effects at the market or product level. For our TWFE estimates, we use the method developed in Roodman, Nielsen, MacKinnon, and Webb (2019) for the confidence intervals. Our Callaway and Sant'Anna (2021) estimations use the Mammen (1993) method.

countries and is preferred over a block bootstrap because the number of clusters varies between 15–118 in the main analyses. Table A.2 in Appendix Section A.2 displays the number of clusters and observations for each reform.

4.3 Timing of Reforms and Choice of Estimation Periods

An important part of our research design is the timing of treatment. Each reform has an actual start date, which is public information, but it is possible that due to anticipation, producers or consumers react to the reform before the reform is implemented. In the context of consumer choice policies, most likely explanation for anticipation is that producers change their pricing strategies before the reform starts. If anticipation is overlooked in the analyses, this behavior can distort our results. Especially in event study analyses, it is important that the reference period is not subject to any anticipation effects. Our DID estimators allow for anticipation, but the start of the anticipation period must be known (Callaway and Sant'Anna 2021).

Our reform timing is in most cases based on the date when the national parliament in question confirmed the law imposing the new price regulation. The benefits of using the confirmation date compared to the actual introduction of the law are that it mitigates anticipation concerns and comes from the legislative process. Our anticipation period starts from the announcement of the reform, because only after a reform has been confirmed there is no uncertainty related to reform details. Some reforms were implemented without changes to the legislation (e.g., the Swedish 2009 IRP $\rightarrow$ Auction-IRP reform); in these cases we rely on other sources to pin down the timing of the reform.

Table 5 shows the duration of each sample period and our timing choices. Column 1 shows the sample period and Column 2 its length (end-start) in months. In selecting sample periods, we limit the overlap between consecutive reforms and at the same time guarantee that the post-reform period is long enough. The shortest sample period is 24 months and the longest 54 months. The Danish 2005 ERP $\rightarrow$ IRP and the Norwegian GS $\rightarrow$ SP 2005 reforms have the shortest sample periods, because the control country (Finland) implements a minor price regulation change that might confound results. In Appendix Section B.9 we present results for these

Table 5: Sample Periods, Reform Start and Reform Timing

Reform	Sample Period	Sample Lenght	Reform Start	Reform Timing	Anticip. Length
	(1)	(2)	(3)	(4)	(5)
Denmark 2000	1999m11–2001m11	24 mths	2000m11	2000m11	0 mths
Denmark 2005	2003m12–2005m12	24 mths	2005m4	2004m12	5 mths
Finland 2003	2001m7–2004m7	36 mths	2003m4	2003m1	4 mths
Finland 2009	2008m2–2012m1	48 mths	2009m4	2009m1	4 mths
Norway 2005	2004m1–2005m12	24 mths	2005m1	2004m9	4 mths
Sweden 2009	2008m4–2012m10	54 mths	2009m5	2009m12	7 mths

Notes: Sample Period = Sample period used in empirical analyses; Sample Length = Lenght of sample period used in empirical analyses; Reform Start = Date on when reform started; Reform Timing = Start of reform anticipation period; Anticip. Length = difference between Reform Start and Timing.

two reforms with a longer follow-up period.

Column 3 in Table 5 shows the actual start dates of the reforms, and Column 4 the reform timing used in our analysis. The duration of the anticipation period is reported in Column 5. The length of the anticipation period varies from 0 months to 7 months while the 4 months is the mode. Half of the studied reforms have a staggered implementation, i.e., different ATC5 markets are affected by the reform at a different point in time. The same anticipation length is applied to all cohorts within a given reform. Only the Danish 2000 IRP $\rightarrow$ ERP and 2005 ERP $\rightarrow$ IRP reforms have immediate reform take-up in all ATC5 markets. The Norwegian 2005 SP reform expands to new markets after our follow-up period ends.

5 Results

We have five headline results. First, reforms directly targeting consumer incentives generate substantial reductions in (average) Expenditure per Dose, while reforms that do not influence consumer incentives result in limited expenditure reductions. Second, we find no short-term adverse effects of price regulation changes on the Number of Product Names (availability of pharmaceuticals), suggesting that implementing consumer choice reforms need not imply a trade-off between pharmaceutical availability and public finances. Third, our results quite clearly suggest that price outcomes are not very informative in understanding how a reform generates cost savings. In particular, with reforms that target consumer incentives, we see that the magnitude of reform treatment effect on (average) Price per Dose is significantly smaller than that on Expenditure per Dose. Consumer choice reforms allow and incentivize consumers to substitute more expensive products with cheaper alternatives, and this demand reallocation mechanism can yield savings even when prices do not change substantially. Fourth, we find that the package- and market-level price regressions yield qualitatively similar results, even though the latter is subject to SUTVA violations arising from strategic producer behavior. Finally, we find no evidence of spillovers between treated markets and those close to treated markets. The absence of spillovers adds credibility to our identification assumptions, but more importantly, demonstrates that regulators can only expect to achieve expenditure reductions in markets directly targeted by regulation.

We first discuss ATT estimates for each studied reform. Anticipation periods are not included in the calculation of ATTs presented in Table 6. We begin with the results from the reforms that had no effect on consumer incentives and progress to reforms that introduced significant incentive changes. For brevity, we present event study results in the Appendix Subsection A.3, as we find no concerning pre-trends and most reforms appear to exhibit stable and almost immediate treatment effects during the follow-up period. We conclude with an analysis of whether the reforms affected nearby markets that were not directly impacted by the reform in question. This analysis serves as a robustness check for us defining markets at the ATC5 level.

Table 6: Average Treatment Effects

	Denmark 2000 IRP → ERP	Denmark 2005 ERP → IRP	Finland 2003 VGS → GS	Finland 2009 GS → IRP	Norway 2005 GS → SP	Sweden 2009 IRP → Auction-IRP
Average Expenditure per Dose	-0.05*	0.04	-0.04	-0.15*	-0.21*	-0.31*
	[-0.09, -0.01]	[-0.01, 0.09]	[-0.09, 0.01]	[-0.21, -0.09]	[-0.29, -0.12]	[-0.38, -0.24]
Number of Product Names	-0.02	-0.01	0.01	0.02	-0.01	0.04
	[-0.06, 0.02]	[-0.05, 0.03]	[-0.04, 0.06]	[-0.05, 0.09]	[-0.15, 0.15]	[-0.02, 0.11]
Average Price per Dose	-0.07*	0.07*	-0.04	-0.04	-0.10	-0.15*
	[-0.12, -0.01]	[0.02, 0.12]	[-0.12, 0.04]	[-0.09, 0.02]	[-0.18, -0.00]	[-0.22, -0.08]
Number of Doses	0.00	0.07*	0.01	0.04	0.04	-0.01
	[-0.04, 0.04]	[0.03, 0.12]	[-0.04, 0.07]	[0.00, 0.07]	[-0.00, 0.09]	[-0.08, 0.07]
Package-level Price per Dose	-0.09*	0.05	-0.06	-0.11*	-0.11*	-0.17*
	[-0.13, -0.05]	[-0.01, 0.12]	[-0.13, 0.02]	[-0.16, -0.06]	[-0.20, -0.01]	[-0.24, -0.10]

Notes: Two-way fixed effects (Denmark 2000 and 2005, Norway 2005) and Callaway and Sant'Anna (2020) (Finland 2003 and 2009, Sweden 2009). Outcome data source: DLI-MI (2007–2013), Farmastat (2004–2013), Fimea (2007–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013). Confidence intervals calculated at the 95% confidence level; * = statistically significant at the 95% level. 10000 replications for ATC-5 wild bootstrapped standard errors.

5.1 Reforms without Consumer Incentive Changes

Table 2 shows that the Danish 2000 IRP → ERP and 2005 ERP → IRP reforms were the only studied consumer choice reforms that did not directly target consumer cost-containment incentives. Instead of consumer incentives, these reforms aimed to affect producer incentives. Our results, presented in Table 6, suggest that the Danish 2000 IRP → ERP reform led to a modest 5% reduction in the Expenditure per Dose. Event study results, presented in the Appendix (Figure A.2a top panel), further show that the IRP → ERP reform quickly reduced the Expenditure per Dose, and the estimated treatment effects stabilized rapidly. At the same time, we find no impact on the Number of Product Names (pharmaceutical availability), and, reassuringly, we also find that the studied reform did not decrease quantity (measured by the Number of Doses). The Danish 2000 IRP → ERP reform illustrates that even when the implemented regulation scheme targeted only producer incentives, it was possible to generate cost savings without compromising pharmaceutical availability. A unique feature of the Danish reforms (2000 IRP → ERP and 2005 ERP → IRP) is their potential to affect monopoly markets, though note that they were excluded from our main analysis. We analyze monopoly markets in Appendix Section A.4 and find results that are consistent with, though noisier than, those reported here.

The underlying mechanism behind the reform performance is that ERP allows Danish regulators to use domestic and foreign price information from Europe to form the reference prices, in contrast to the pre-reform (IRP) regime, where regulators could only use domestic prices. However, the price information the regulator has access to is tied to the package match-rate between the domestic market and neighboring countries. Firms that sell their products in Denmark but do not have comparable products available in one of the reference countries are not required to submit their foreign prices to the Danish regulator. Our results imply that the price levels of off-patent pharmaceuticals were higher in Denmark before the reform than in its reference countries. A decrease in reference prices can lead to demand reallocation from more expensive to cheaper products, and simultaneously, price competition between producers can intensify. Indeed, we find that the reform decreased both studied price measures. The (average) Price per Dose, which is a market-level price measure, decreased by 9%, and the package-level price per

dose decreased by 7%. Interestingly, both price outcomes yield qualitatively similar results, even though the package-level price analysis violates SUTVA.

In 2005, the ERP → IRP reform reversed the earlier policy change by excluding foreign prices from reference price calculations, such that the reform's impact on firm incentives has the inverse logic of the earlier Danish IRP → ERP policy change, making the 2005 reform the only studied reform designed to reduce firm incentives to compete. Unsurprisingly, we find that the ERP → IRP reform increased the average expenditure per dose by 4%. As shown in Table 6, the increase in Expenditure per Dose is driven by both increased prices and market expansion. Specifically, the Price per Dose increased by 7%, and the Package-level Price per Dose increased by 5%. Interestingly, decreased firm incentives and a higher price level do not result in significant changes in the Number of Product Names. Our result on quantity (measured as Number of Doses) is somewhat anomalous, as we find substantial market expansion combined with price increases.

It is worthwhile to note that, even though the ATT estimates for the Danish 2005 ERP → IRP reform are not statistically significant, the event study results presented in the Appendix (Figure A.2b top panel) show that the estimated leads for Expenditure per Dose begin to increase after the reform has been in place for four months. This is the only reform that does not have an immediate effect on Expenditure per Dose, likely because firms needed time to re-optimize their prices. Since the DID estimator measures changes in price relative to the control group, the positive treatment effect is most likely due to prices either stabilizing or decreasing more slowly in Denmark than in the control country (Finland). The follow-up period is relatively short because minor price regulation policies in the control country (Finland) limit the period length. We estimate the effects beyond a 12-month period in Appendix Section B.9 and present the results in Appendix Figure 13a. Results from the longer follow-up period document that the Expenditure per Dose continues to increase beyond the main observation period.

Our conclusions on the effects of the Danish 2005 ERP → IRP reform differ from earlier research on this reform. Kaiser, Mendez, Rønde, and Ullrich (2014) report substantial price decreases, whereas we find the opposite. The differences likely stem from variations in the markets and methods analyzed. Our DID setup covers all generic markets that satisfy our sample selection criteria, while Kaiser,

Mendez, Rønde, and Ullrich (2014) focus on the statin market using a before-after setup. We do not attempt to replicate the findings of Kaiser, Mendez, Rønde, and Ullrich (2014), because their analysis of the statin market in Denmark involves only six different active ingredients during the Danish 2005 ERP → IRP reform.

5.2 Reforms with Small Consumer Incentive Changes

The Finnish VGS → GS 2003 reform was the only studied reform that provided small-scale cost-containment incentives to consumers (see Table 2). This reform allowed consumers the possibility to substitute to a cheaper product at the pharmacy without consulting a physician, and consumers also received information on substitutable products while visiting the pharmacy. The reform mildly nudged pharmaceutical demand towards cheaper products because consumers could lower their out-of-pocket costs by substituting to cheaper products. However, the reimbursement system was not used to direct consumer demand toward cheaper products, meaning that consumers could receive full reimbursement even when buying expensive products.

Table 6 shows that the VGS → GS reform decreased the Expenditure per Dose by 4% without any effect on the Number of Product Names or on Number of Doses quantity). It is important to note that all ATT estimates related to this reform are statistically insignificant. The event study results presented in the Appendix (Figure A.3a top panel) show that the reform had an instant but imprecise effect on Expenditure per Dose that appears to decline slightly towards the end of the follow-up period. Meanwhile, the Number of Product Names experiences a small, positive, but insignificant increase, which also reverts towards zero at the end of the follow-up period (Appendix Figure A.3a bottom panel). Our price results suggest that the observed expenditure reductions are primarily attributable to decreased prices, as the size of the decrease in Price per Dose (4%) matches the reduction in the Expenditure per Dose (4%). Interestingly, demand reallocation from expensive products to cheaper generic alternatives does not explain the reduction in average expenditure, a finding that stands out given that the Finnish VGS → GS 2003 reform expanded the consumer choice set and allowed consumers to make prescription substitutions directly at the pharmacy. One plausible explanation

is that allowing consumers to make choices without proper financial incentives is not an effective way to curb pharmaceutical expenditure within the context of a generous cost-sharing system between consumers and regulators. We explore this hypothesis further in the context of the Finnish GS → IRP 2009 reform, which introduced financial incentives on top of this reform.

5.3 Reforms with Moderate Consumer Incentive Changes

The Finnish GS → IRP 2009 and Norwegian GS → SP 2005 reforms are categorized as having moderate impacts on consumer cost-containment incentives (see Table 2). The Finnish GS → IRP 2009 reform influenced consumer incentives by changing how reimbursements were calculated when consumers can make choices between substitutable alternatives. After the policy change, consumers received reimbursement on the basis of the reference price, which was determined from the lowest price of substitutable products. If a consumer chose not to purchase a reference-priced product, they were required to pay the difference between the reference price and their chosen product fully out-of-pocket.

Table 6 displays that the Expenditure per Dose decreased by 15% after Finland implemented the IRP reform in 2009. Compared to the earlier Finnish VGS → GS 2003 reform, the magnitude of the expenditure decrease is more than three times larger, and we do not observe any adverse effects on Number of Product Names (pharmaceutical availability) or on Number of Doses (quantity). Event study results presented in the Appendix (Figure A.4a top panel) suggest that the GS → IRP reform produced an almost instant reduction in Expenditure per Dose that remains roughly constant throughout the follow-up period. Meanwhile, the Number of Product Names slightly increases at the beginning of the follow-up period but later reverts to zero (Figure A.4a bottom panel). We also find negative price effects, with the Price per Dose decreasing by 4% and the Package-level Price per Dose decreasing by 11%. Here, the level of aggregation plays a key role in interpreting price results. This is one of the few instances where the two studied price outcomes do not yield the same result. The magnitude of these price reductions (especially the decrease in Average Price per Dose), combined with the slight market expansion, cannot fully explain the reduction in average expenditure. Demand reallocation

from more expensive products to cheaper alternatives offers one possible explanation for the observed decrease in average expenditure. Additionally, the GS → IRP reform's incentive structure further supports this interpretation.

There is a strong case to be made for why the Finnish GS alone had only a limited effect, while the Finnish IRP generated substantial cost savings. First, the GS policy simply expanded the choice set of consumers. Although a generic alternative might have been priced lower than the branded product, deciding against substitution did not affect the level of reimbursement or co-payment borne by the consumer. Consequently, consumer incentives to accept substitution were low, particularly for fully reimbursed products and for those who had exceeded their annual maximum out-of-pocket costs. To further investigate this, we performed a subgroup analysis based on the different reimbursement categories of the products, the results of which are presented in Online Appendix Section B.5, Figure B.4.[24] As anticipated, we find that package-level price decreases are the largest and statistically significant for products receiving only basic levels of reimbursement. In contrast, the point estimates for products with full 100% reimbursement are negligible, indicating that the Finnish 2003 VGS → GS reform did not succeed in decreasing the prices of products that benefited from the most generous public subsidies. In contrast, the adoption of IRP in 2009 resulted in substantial price decreases and cost savings, including products with full public reimbursement—the same products that were less affected by the earlier 2003 VGS → GS reform.

The Norwegian GS → SP 2005 reform provided moderate cost-containment incentives for consumers, similar to the Finnish 2009 reform, but it also had a limited impact on the incentives of wholesalers and pharmacies. In the Norwegian reform, pre-specified government rules dictated the evolution of the reference price after patent expiry. The SP regulation assigns the same price cap to both the original patented product and its generic alternatives, and the original price cap is calculated based on an average of the prices of the original products in other European Economic Area (EEA) countries. Typically, the price cap is either binding or close to binding for the branded product. Because the SP system forced

24. This subgroup inquiry is based on a product (package)-level analysis rather than market-level analysis, as the reimbursement statuses are defined at the package-level. The results underscore the weakness of the GS policy when applied without reference price regulation, but the analysis is potentially affected by SUTVA violations.

a gradual decrease in this price cap, the largest price decreases can be expected for products where the price cap was binding.[25] The reform also required pharmacies to have at least one product at or below the step-price (reference price) available in stock. It is worth noting that after the adoption of the SP model, pharmacy chains had limited incentive to sell generics at prices lower than the maximum retail price (the price cap plus the retail margin).

The peculiar feature of this reform is that it directly regulates reference prices instead of relying on market competition between producers after patents expire to determine reference prices. Regulation like this has the potential to achieve considerable cost savings, but the obvious concern is the potential detriment to pharmaceutical availability. Table 6 shows that the Expenditure per Dose decreased by 21%, and our event study analysis indicates that the treatment effect occurred almost immediately. Moreover, the time-varying treatment effects on Expenditure per Dose remained approximately constant throughout the follow-up period (Appendix Figure A.4b top panel). Simultaneously, we do not observe any adverse effects on the Number of Product Names (Table 6). Event study results, reported in Appendix Figure A.4b (bottom panel), show that the reform had a small, yet almost time-invariant, positive effect on the Number of Product Names. Similarly, we find no evidence of effects on market size. Table 6 also shows that the reform induced significant price reductions, with Price per Dose decreasing by 10% and Package-level Price per Dose decreasing by 11%. However, price decreases are smaller in absolute value than the reduction in Expenditure per Dose. Our suggested interpretation is that firms responded to increased consumer incentives by lowering prices while, simultaneously, consumer demand shifted toward cheaper products. Thus, strict regulation yielded substantial cost savings and we find no evidence of short-term adverse effects on pharmaceutical availability. An important limitation of the results for the Norwegian GS $\rightarrow$ SP reform is the short follow-up period of only 15 months, as Finland (the control country) implemented a minor price regulation change (a price cut) in January 2006. We extend the analysis in Appendix Section B.9, Figure 14a, where we present results for a longer post-period of 20 months which are qualitatively consistent with the main results.

25. We display the SP rule for our observation period in Online Appendix Table B.5.

5.4 Reforms with Major Consumer Incentive Changes

The Swedish 2009 GS → Auction-IRP reform is the only reform that significantly affected both consumer and firm incentives through an extensive overhaul of market institutions (Table 2). The pre-reform regime in Sweden was similar to Finland's system adopted in 2009, i.e., IRP. However, in Sweden, customers were reimbursed only when purchasing the cheapest product in the pharmacy or the prescribed product even before this reform. The reform further augmented consumer incentives by requiring consumers to substitute to the cheapest product at the national level to receive reimbursement. The cheapest products were determined through national monthly Auction-IRP auctions, which created strong incentives for firms to compete, as the auction winner could anticipate capturing a significant market share.

Given the characteristics and implementation of the reform, it is unsurprising that this reform generates the largest cost savings compared to other reforms studied in this paper. Table 6 shows that the Swedish 2009 GS → Auction-IRP reform decreases Expenditure per Dose by 31%, and the decreases Price per Dose by 15%. The magnitude of these results is by an order of magnitude larger than those observed in the other reforms. This highlights that when a reform is specifically designed to reallocate demand to a particular product, the established estimation strategy of consumer choice reforms of studying average prices instead of expenditure would have provided a severe underestimate of the effectiveness of this regulation (31% vs. 15%). Event study results, presented in Appendix Figure A.5a, show that the GS → Auction-IRP reform rapidly reduces Expenditure per Dose, and the treatment effect stabilizes quickly. Furthermore, our event study analysis demonstrates that expenditures begin to decrease during the anticipation period. Although we observe anticipation effects in other reforms, the size of the anticipation effect in this reform is substantially larger than in the other reforms. Given the expenditure and prices results, it is particularly interesting that we find no negative effects on the Number of Product Names or quantity. The Swedish Auction-IRP reform is specifically designed to divert demand to the cheapest product, and the results presented in Table 6 support the hypothesis of demand reallocation from expensive products to cheaper alternatives. Part of the decrease in expenditure can be attributed to intensified price competition between pharmaceutical producers,

but price changes alone cannot explain the observed expenditure reduction.

The importance of the results for the Swedish auction system should not be underestimated. By combining an auction with strong restrictions on the set of reimbursable products, the reform significantly increased competition. In practice, the winner of the monthly auction can anticipate capturing a very large share of the market. Our results suggest that the Swedish reform is highly effective in curtailing expenditure—the primary goal of pharmaceutical price regulation. However, it is important to note that the auction format was introduced almost simultaneously with a tightening of the maximum wholesale price regulation. Our reduced-form approach does not allow us to disentangle the specific effects of the auction format and those of the tightened maximum wholesale price regulation. Details regarding these minor price regulation changes are provided in Appendix Section B.3.7.

The Swedish 2009 IRP $\rightarrow$ Auction-IRP reform is the second reform where we can test the robustness of the research design using different control groups. In our preferred specification, we use Denmark as the control group. As a robustness check, we use either Norway or a combination of Denmark and Norway as the control group. We can thereby assess what happens when we change from a control country (Denmark) that shares the baseline regulation status with the treated country to a control country (Denmark, Norway) that does not (Tazhitdinova and Vazquez-Bare 2023). We find that our results remain robust regardless of the choice of the control group, even though the baseline regulation differs (see Online Appendix B.6).

5.5 Spillovers Between Pharmaceutical Markets

The existing literature has examined the spillovers of regulation to markets not directly affected by the reform. We have defined markets at the active ingredient, i.e., ATC5 level, but there are diseases that are treated with pharmaceuticals from more than one ATC5 class. It is therefore possible that a reform indirectly affects those markets that are not directly affected. Spillovers of this type are referred to as therapeutic competition, and in some studies, the effect of therapeutic competition on prices has been found to be economically significant (Brekke, Grasdal, and Holmås 2009; Brekke, Holmas, and Straume 2011).

In our test for spillovers, the treatment group consists of ATC5 markets in the treatment country that share the same ATC4 class as an affected ATC5 market but are not directly affected by the reform. Sharing the same ATC4 class means that products belong to the same chemical subgroup. The control group consists of the same ATC5 markets in the control country. We use the same estimation methods as in the main analysis and report the ATTs in Table 7. The Danish reforms (2000 and 2005, from IRP to ERP and back) are excluded because these reforms influenced all products. The results for the monopoly Danish markets are discussed and reported in Appendix Section A.4.

The estimated spillover effects on Expenditure per Dose are small in absolute magnitude, negative in sign and statistically insignificant. The effects on Number of Product Names (pharmaceutical availability) are consistently very small in magnitude. Turning to prices and quantities, our market- (Price per Dose) and package-level (Package-level Price per Dose) price estimations deliver small and insignificant estimates. The one statistically significant (positive) quantity effect—for the Norwegian IRP $\rightarrow$ SP reform—is possibly a statistical fluke given that the reform was estimated to have no meaningful quantity effect on the directly affected ATC5 markets. All in all, these results support our decision to define the relevant market at the ATC5 active ingredient level.

6 Conclusions

We investigate the causal effects of different price regulation policies and changes in the incentives of pharmaceutical producers, wholesalers, pharmacists and patients, on pharmaceutical expenditure and product availability in the Nordic pharmaceutical markets facing generic competition. Such policies are globally important because pharmaceutical spending has been increasing and because public and private health insurance schemes in many countries have reduced or even removed the price sensitivity of patients which, given the product, may not be that high to start with. We combine product-level price, quantity, and sales information with extensive information on different regulatory policies and market institutions that were in place 1999–2010 and analyze the effects of several reforms.

The regimes in our data can be classified based on how the price regulation

Table 7: Average Treatment Effects (Spillover Samples)

	Finland 2003 VGS → GS	Finland 2009 GS → IRP	Norway 2005 GS → SP	Sweden 2009 IRP → Auction-IRP
Average Expenditure per Dose	-0.01	-0.02	-0.03	-0.01
	[-0.05, 0.04]	[-0.06, 0.02]	[-0.10, 0.05]	[-0.10, 0.10]
Number of Product Names	-0.01	0.01	-0.02	0.03
	[-0.03, 0.02]	[-0.03, 0.05]	[-0.08, 0.04]	[-0.03, 0.09]
Average Price per Dose	-0.02	-0.00	0.00	-0.02
	[-0.06, 0.02]	[-0.13, 0.15]	[-0.05, 0.07]	[-0.08, 0.04]
Number of Doses	0.08	0.01	0.13*	0.12
	[0.00, 0.16]	[-0.11, 0.14]	[0.01, 0.26]	[-0.13, 0.43]
Package-level Price per Dose	0.00	-0.02	-0.04	-0.02
	[-0.01, 0.01]	[-0.04, 0.01]	[-0.12, 0.04]	[-0.04, 0.01]

Notes: Two-way fixed effects (Norway 2005) and Callaway and Sant'Anna (2020) (Finland 2003 and 2009, Sweden 2009). Outcome data source: DLI-MI (2007–2013), Farmastat (2004–2013), Fimea (2007–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013). Confidence intervals calculated at the 95% confidence level; * = statistically significant at the 95% level. 10000 replications for ATC-5 wild bootstrapped standard errors.

reforms influenced the incentives of different market participants. Our results suggest that reforms focusing solely on consumer incentives are effective, but those addressing both consumer and producer incentives are the most successful. The effects on expenditure were, with one exception, greater than those on prices for the four successful reforms that reduced expenditure. This is likely explained by the fact that the successful reforms introduced stronger financial incentives for patients to choose cheaper drugs within the same ATC5 group, leading to a demand reallocation towards cheaper products. This implies that the existing literature that relies heavily on estimating the effect of regulations on prices may have underestimated the effectiveness of price regulations in curbing expenditure.

Despite the large effects on expenditure, the reforms did not have an adverse effect on product availability, and their effect on quantity was nonexistent or moderate and positive. A potential explanation for the lack of detrimental availability results is that in many cases expenditure decreases are driven by demand reallocation instead of large price decreases. This could mean that modest price decreases were too low to induce shortages. The very small estimated quantity effects suggest highly inelastic demand, meaning that expenditure savings roughly translate to increases in consumer surplus. The studied consumer choice policies do not appear to have any meaningful spillovers to non-regulated markets. This implies that

the regulator must find alternative ways to contain costs in markets where choice policies cannot be implemented. Our results suggest that regulations that combine maximum price regulation in markets with intensive forms of generic competition and steep patient incentives to facilitate competition may be a powerful tool to decrease pharmaceutical expenditure without having to compromise pharmaceutical availability. In drawing policy conclusions from our results one should keep in mind that we were only able to study availability over a short period of time, and our results do not rule out the possibility of local or short-term availability problems.

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A Appendix

A.1 Data Sources and Sample Statistics

Data sources. Our data sources are detailed in Table A.1.

Table A.1: Sales Data Coverage and Data Sources

	Years	Source
Panel A: Sales Data		
Finland	1998–2017	FIMEA
Sweden	2006Q2–2017	IQVIA
Denmark	1991–2017	DLI-MI
Norway	2000–2018	Farmastat
Panel B: Reform Data		
2000 Denmark	1999–2005	Legislation
2003 Finland	2003–2009	FIMEA+Legislation
2005 Denmark	2003–2007	Legislation
2005 Norway	2003–2007	NOMA+Legislation
2009 Finland	2009–2015	PPB+Legislation
2009 Sweden	2005–2013	TLV+Legislation

Notes: FIMEA = Finnish Medicines Agency; PPB = (Finnish) Pharmaceutical Pricing Board; NOMA = Norwegian Medicines Agency; TLV = (Swedish) Dental and Pharmaceutical Benefits Agency.

Number of observations. Our sample sizes are detailed in Table A.2. Panel A displays market-level statistics by reform, and Panel B displays the same for product-level outcomes. The Norwegian 2005 IRP → SP reform has the smallest market and product level sample size and the Swedish 2009 IRP → Auction-IRP reform has the largest market and product level sample size. Table A.2 Panel C and D denote the sample sizes for spillover and monopoly analyses at the market and product level by reform. The two Danish reforms are the monopoly analyses, while other samples in Panels C and D consider the spillover analyses. The monopoly

sample sizes are much larger than other samples because these samples contain all monopoly markets that meet our sample selection criteria laid out in Section 3.3.

Table A.2: Number of Observations and Clusters

	Denmark 2000	Denmark 2005	Finland 2003	Finland 2009	Norway 2005	Sweden 2009
Panel A: Market Level						
Number of Observations	2842	6716	4884	9939	1110	12211
Number of Clusters	59	118	80	105	15	112
Panel B: Product Level						
Number of Observations	58377	116703	79756	138476	24780	224105
Number of Clusters	59	118	80	105	15	112
Panel C: Market Level (Spillover and Monopoly)						
Number of Observations	24153	32316	3537	5979	3014	9474
Number of Clusters	727	771	71	77	44	118
Panel D: Product Level (Spillover and Monopoly)						
Number of Observations	108411	142654	16947	21203	37684	82728
Number of Clusters	727	771	71	77	44	118

Notes: This table presents the number of observations and number of bootstrap cluster by each estimation (reform). Panel A gives market level statistics from Average Expenditure estimations. Panel B gives product level statistics from Wholesale Price estimations. Other outcomes might have slightly different values due to missing values. Outcome data source: DLI-MI (1999–2013), Farmastat (2004–2013), Fimea (1999–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013).

Table A.3: Package-level Matching Rates

	Treatment (1)	Control (2)	Union (3)	Union-% w.r.t treatment (4)
Denmark 2000	1551	1098	250	16.12
Denmark 2005	2183	2146	454	20.80
Finland 2003	1654	1936	369	22.31
Finland 2009	2393	1393	392	16.38
Norway 2005	331	484	93	28.10
Sweden 2009	2870	2914	610	21.25

This table lists the package level match rates between the treatment and control countries in all estimations. Outcome data source: DLI-MI (1999–2013), Farmastat (2004–2013), Fimea (1999–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013).

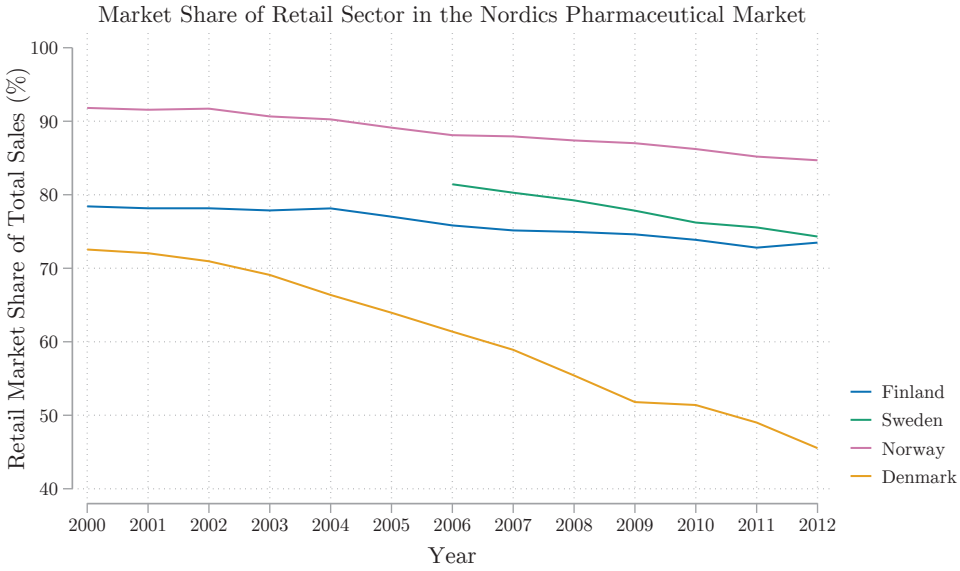
A.2 Additional Descriptive Statistics

Share of identical products in treatment and control countries. Nordic countries that use ERP-policies include other Nordic countries in their ERP-baskets, and this can facilitate regulation spillovers or externalities between treatment and control countries. ERP-policies used in the Nordics compare prices at the package-level and hence the relatively small product overlap means that ERP is not likely to invalidate our cross-country research design. In Table A.3 we calculate how the share of products (packages) sold in a treatment country that is also sold in the control country.

Table A.3 shows the number of unique packages and the number of identical packages in estimation samples by each reform during the reform pre-period. Column 1 shows the unique number of products in the treatment country and Column 2 shows the same for the control country. Column 3 displays the number of identical unique packages that are found in both treatment and the control country and Column 4 shows how large a share of the treatment country packages are present in both countries during the pre-period. The overlap between products being sold in both countries during the pre-period varies between 16% and 28%.

The role of the hospital market. Pharmaceuticals are distributed through

Figure A.1: Aggregate Pharmacy Market Share



The development of the retail market share in the Nordics pharmaceutical market from 2000 to 2012.
Data source: DLI-MI, Farmastat, Fimea, IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2000–2012).

pharmacies and hospitals in the Nordic countries. We concentrate on the pharmacy market: Figure A.1 shows the share of pharmaceuticals sold through pharmacies (shares are calculated using wholesale prices).[26] The share of pharmaceuticals distributed through pharmacies has been quite stable in Finland, Sweden, and Norway during our observation period. However, in Denmark the share of pharmaceuticals distributed through pharmacies decreased during our observation period from around 70% to less than 50%.

A large hospital share of pharmaceutical sales can be problematic in our cross-country matching procedure because it is possible that a given ATC5 market in Denmark has only hospital market sales, leading to unmatched markets. This turns out to be only a minor concern The difference between Columns 3 and 4 of Table 4 in the main text illustrates the number (Panel A) and economic significance (Panel

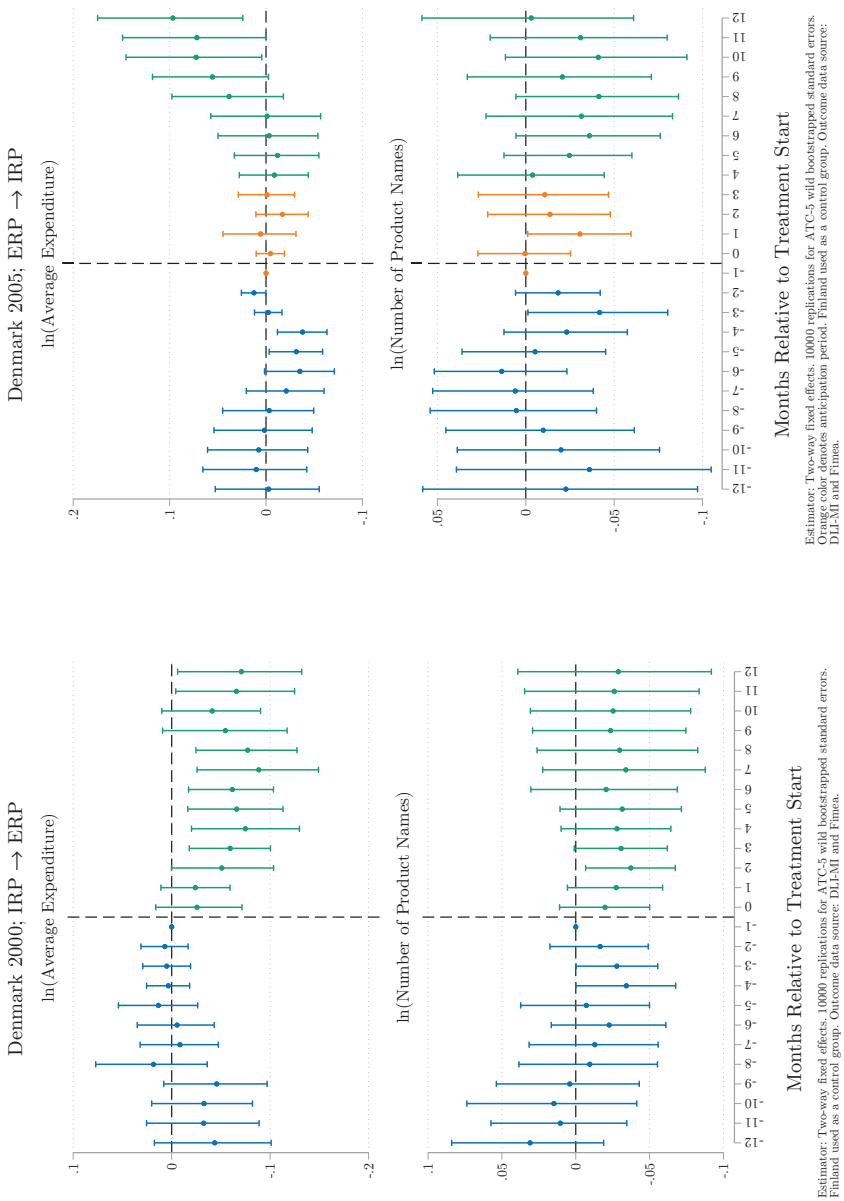
26. The Nordic hospital pharmaceutical market works through competitive bidding. Unfortunately, we do not have access to bids and therefore we need to rely on wholesale prices while calculating market shares. This leads to a situation where the market shares presented in Figure A.1 are the upper bound of the actual market share.

B) of unmatched markets. All comparisons in which Denmark is used as a control group have unmatched markets, but the economic significance of these markets in the treated country is small (1%–5% of the sales of the generic market).

A.3 Event Study Results

This subsection presents event study results for each studied reform. Event study results are presented in the same order as in the main text.

Reforms without Consumer Incentive Changes The Danish 2000 IRP → ERP reform leads to an average 5% decrease in average expenditure per dose (Figure A.2a, top panel). The point estimates for availability are quite stable at roughly -2%, but statistically insignificant (Figure A.2a, bottom panel). The results are highly symmetric when studying the 2005 ERP → IRP reform: Average expenditure increased by roughly 4%, while the change in availability is not statistically significant.

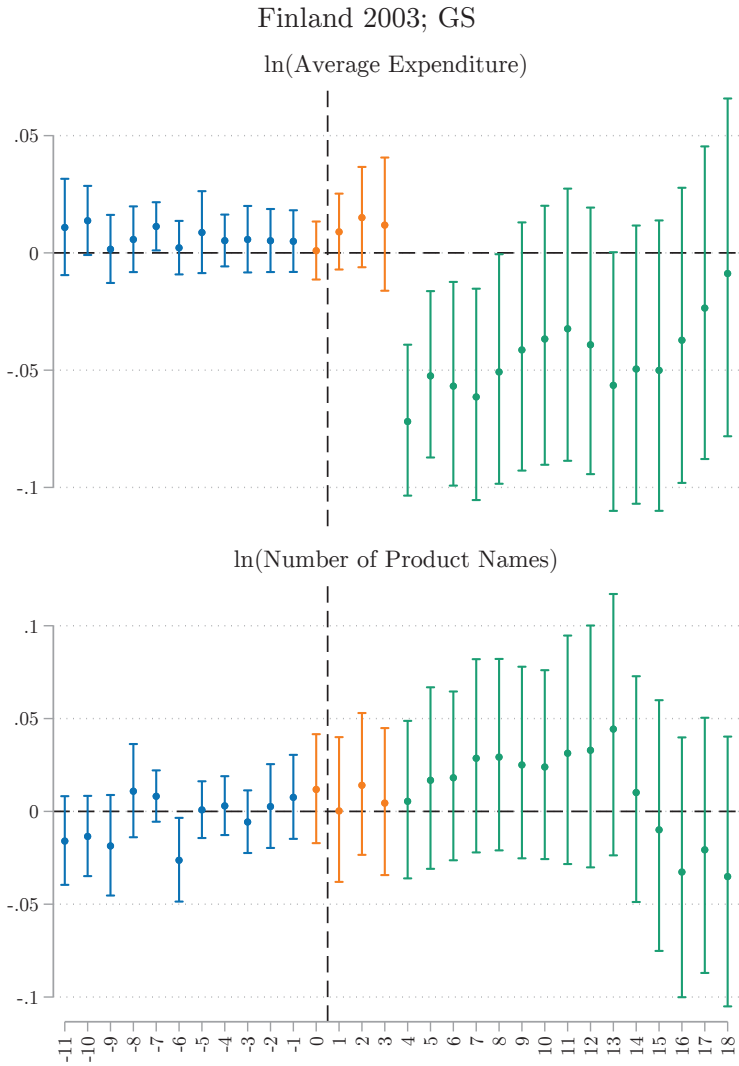


(a) Denmark 2000

(b) Denmark 2005

Figure A.2: Reforms without Consumer Incentive Changes

Reforms with Small Consumer Incentive Changes The event study results for Finnish 2003 VGS → GS reform are shown in Figure A.3a: They suggest that immediately after implementation there was a 7% decrease in average expenditure (Figure A.3a, top panel), but the effect decreases in magnitude and becomes statistically insignificant as time passes (also, the confidence intervals of any pair of treatment period point estimates overlap). The point estimates on availability (Figure A.3a, bottom panel) are positive until post-period 14 but very imprecise.



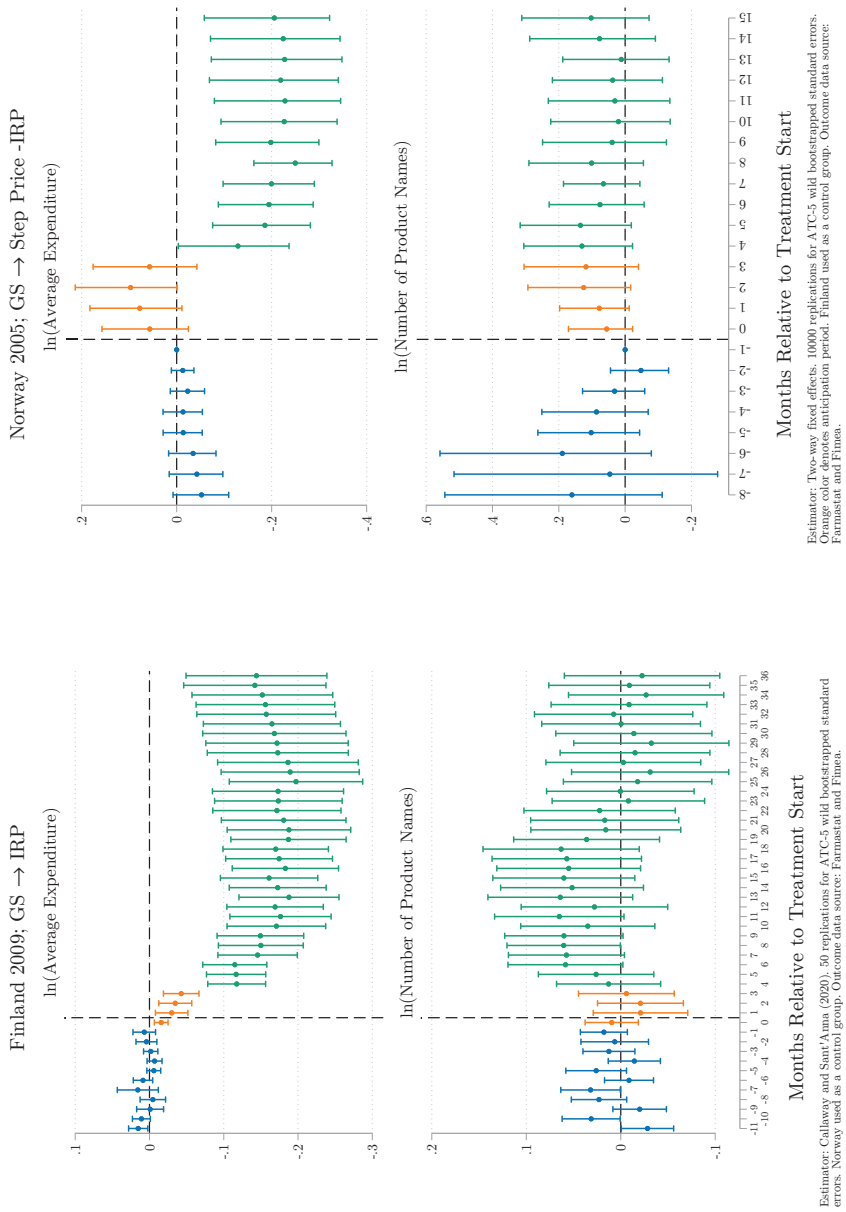
Estimator: Callaway and Sant'Anna (2020). 10000 replications for ATC-5 wild bootstrapped standard errors. Denmark used as a control group. Outcome data source: DLI-MI and Fimea.

(a) Finland 2003

Figure A.3: Reforms with Small Consumer Incentive Changes

Reforms with Moderate Consumer Incentive Changes Event study results for Finnish 2009 GS → IRP reform are presented in Figure A.4a. We find in Figure A.4a (top panel) that the adoption of IRP decreased average expenditure by 16% a year after the implementation of the reform; again all point estimates' confidence intervals overlap, but the estimate sizes seem to start to decline in absolute terms in the last 12 months. The point estimates on availability (Figure A.4a, bottom panel) vary. All point estimates are noisily estimated and the absolute value of estimates seems the decrease during the follow-up period. Importantly, the results do not support the idea that this reform would have decreased availability.

Our event study results for Norwegian 2005 GS → SP reform, shown in Figure A.4b (top panel), reveal that average expenditure per dose decreased by approximately 21%. The number of product names is not affected (Figure A.4b, bottom panel): The point estimates are positive but imprecisely measured.



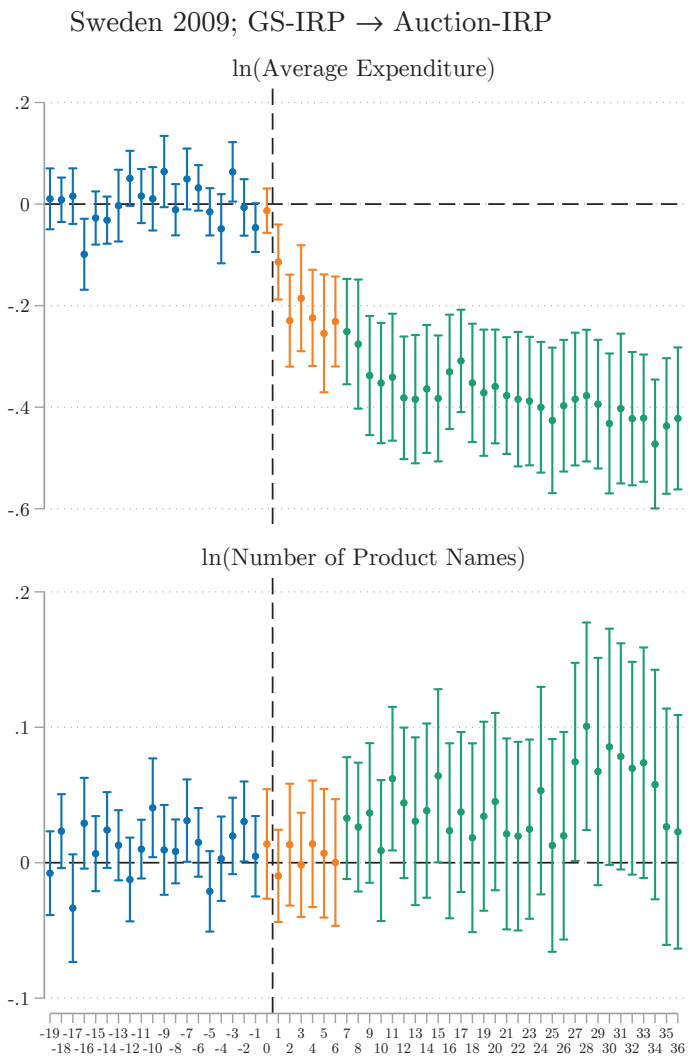
(a) Finland 2009

(b) Norway 2005

Figure A.4: Reforms with Moderate Consumer Incentive Changes

Reforms with Major Consumer Incentive Changes The results of the Swedish 2009 GS → Auction-IRP reform are reported in Figure A.5a. Our event study estimates suggest that the reform led to statistically significant decreases between 24%–38% in average expenditure per dose (Figure A.5a, top panel; note that again the point estimates are within each others' confidence intervals).[27] Consistent with our previous results, even a reform with a large effect on expenditure seems to have no discernible effect on the availability of products (Figure A.5a, bottom panel).

27. 24%–38% refer to ATT estimate confidence intervals presented in main text Table 6.



Estimator: Callaway and Sant'Anna (2020). 10000 replications for ATC-5 wild bootstrapped standard errors. Orange color denotes anticipation period. Denmark used as a control group. Outcome data source: DLI-MI, IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013).

(a) Sweden 2009

Figure A.5: Reforms with Major Consumer Incentive Changes

Table A.4: Average Treatment Effects (Monopoly Samples)

	Denmark 2000 IRP → ERP	Denmark 2005 ERP → IRP
Average Expenditure per Dose	-0.04*	0.01
	[-0.06, -0.02]	[-0.01, 0.02]
Number of Product Names	0.02	-0.00
	[0.00, 0.04]	[-0.02, 0.02]
Average Price per Dose	-0.04*	0.01
	[-0.06, -0.02]	[-0.00, 0.03]
Number of Doses	-0.04	0.00
	[-0.08, 0.01]	[-0.04, 0.04]
Package-level Price per Dose	-0.06*	0.02*
	[-0.07, -0.05]	[0.01, 0.03]

Notes: Two-way fixed effects. Outcome data source: DLI-MI (1999–2006) and Fimea (1999–2006). Confidence intervals calculated at the 95% confidence level; * = statistically significant. 10000 replications for ATC-5 wild bootstrapped standard errors.

A.4 The Danish 2000 IRP→ERP and 2005 ERP→IRP Reforms: Monopoly Markets

The main analysis showed results on Danish 2000 IRP → ERP and 2005 ERP → IRP reforms for generic markets. These reforms affected also non-generic (= monopoly) markets, and this Subsection presents the effects on monopoly markets. The analysis of monopoly markets is an important addition to the discussion of how ERP-like regulatory measures work. The structure of the analysis and sample matching is the same as before; the only change is that the focus is on markets where generic competition has not started yet. The results are displayed in an event study format and are also summarized as ATT measures.

Table A.4 shows that both average expenditure and average price decreased by -4% on during the IRP → ERP reform of 2000 and increased statistically insignificantly by 1% and 2% during the ERP → IRP reform of 2005.

The main takeaway from the results presented in this Subsection is that ERP policies have the ability to influence the pricing and sales of pharmaceuticals also when the market is not subject to generic competition. This means that ERP

can be used to augment simple price cap regulation when price competition-based regulation cannot be used. However, it is important to note that implementation of ERP policy could also have adverse effects on reference countries, because firms could have an incentive to increase prices or delay entry in order to dilute the benefits of using ERP (Dubois, Gandhi, and Vasserman 2022; Maini and Pammolli 2023). The results from a (small) Nordic country might not be directly applicable to a larger country because it is possible that implementation of ERP in a small geographical market might not cause large adverse effects compared to a situation where ERP is implemented in a larger country.

B Online Appendix

B.1 Nordic Countries, Reimbursement systems and Pharmacy Markup-rules

This Subsection provides an overview of the four Nordic countries included in this study. All Nordic countries are welfare states and follow similar economic and social policies. The Nordic (welfare) model explains why many aspects related to pharmaceutical markets are similar in these countries (Bhattacharya, Hyde, and Tu 2013). We provide additional details on on the reimbursement systems in use, the pharmacy markup-rules, on pharmacy and physician incentives related to prescribing, detailing and on the evolution of core demographic trends behind pharmaceutical demand.

Country overview. Table B.1 displays some relevant descriptive statistics of the four countries. All countries except Norway are EU members. All four countries belong to the EEA, meaning that Norway also follows many EU regulations. Finland is the only Nordic country without her own national currency, having adopted the Euro in 2002. In 2007 Sweden had the largest population, more than 9 million, while Norway's population of 4.7 million was the smallest. The percentage of population aged 65 years and older was also highest in Sweden and lowest in Norway. In 2007, GDP per capita was highest in Norway and lowest in Finland. Sweden had the largest pharmaceutical market with total sales of more than 2.7 billion euros in 2007, while Norway had the smallest market with sales of 1.46 billion euros. At 8.5%, the Swedish pharmaceutical market was also the largest relative to GDP. In Finland and Denmark, the pharmaceutical market represented approximately 6.3% of GDP, and in Norway 3.3%.

Reimbursement systems. Table B.2 summarizes the reimbursement (cost-sharing) systems in the Nordic countries. Although the reimbursement systems are quite similar, individual countries have different reimbursement rates and annual out-of-pocket ceilings. The Finnish reimbursement system is the least generous, because the smallest reimbursement rate is 42% and the annual out-of-pocket cost ceiling is 610 euros, almost three times higher than in Norway or Sweden.

There are two distinct approaches to public reimbursement of pharmaceutical

Table B.1: Nordics Descriptive Statistics

	Population	Population aged 65 and above, %	EU Member	EEA Country	Currency	GDP per capita	Market Size, €Mio	GDP share, %
Denmark	5.4	15.5	Yes	Yes	Danish krone	30800	1947	1.16
Finland	5.3	16.5	Yes	Yes	Euro	29900	1879	1.19
Norway	4.7	14.6	No	Yes	Norwegian krone	44200	1444	0.70
Sweden	9.1	17.4	Yes	Yes	Swedish krona	32300	2862	0.97

Notes: The values are from 2007 and population is expressed in millions. The second column displays the percentage of total population that were aged 65 and above. The EU member column indicates whether a country is an European Union member state and the EEA country column indicates whether the countries belong to the European Economic Area. The currency column shows which currency is used in each country. GDP per capita is expressed in euros (PPS). Market size is expressed in millions of euros and is calculated as the sum of sales using pharmacy purchase prices (wholesale prices) in 2007. Market share denotes the share that the pharmaceutical market forms of the country's total GDP. Outcomes data source: DLI-MI, Farmastat, Fimea, IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007).

in the Nordic countries: A needs-based and a product-specific calculation. In the needs-based system, used in Sweden and Denmark, the level of reimbursement and the consumer's co-payment are tied and capped to the consumer's annual pharmaceutical spending. The share of reimbursement (co-payment) increases (decreases) as the consumer spends more on reimbursed pharmaceuticals. After crossing a legal threshold, the consumer is fully reimbursed. In addition, the state typically grants full reimbursement for certain drugs and vulnerable groups. In the product-based reimbursement system, used in Finland and Norway, public reimbursement varies product by product. The level of reimbursement (usually 40% to 100%) is based on the severity of the disease; however, annual consumer spending is capped as in the needs-based system. The crucial difference is that in the needs-based system, conditional on the price negotiations with the manufacturer, the government only decides whether a product receives reimbursement or not. In the product-specific reimbursement system, the government also decides on the level of reimbursement product by product.

Pharmacy mark-ups. All countries except Norway have an exact mathematical formula for the pharmacy mark-up, i.e., pharmacies do not decide retail prices. Norwegian pharmacy system allows vertical integration between pharmaceutical wholesalers and pharmacies since 2001. In other Nordic countries pharmacies that we study pharmacies are not allowed to integrate with wholesalers. Table B.3 shows how these formulas (we display formulas for 2009) convert the pharmacy purchase price (PPP) into the pharmacy retail price (PRP), which is the price from which reimbursements are calculated. Pharmacy purchase prices are set by pharmaceutical firms. The main takeaway from the table is that the retail price

Table B.2: Reimbursement Systems in the Nordics

	Reimbursement % **	Annual out-of-pocket ceiling	Out-of-pocket threshold	Time period for annual ceiling	Reference countries (2012)	Type of referencing	Annual reimbursement expenditure
Panel A: Product specific							
Finland	Basic: 42% Lower special: 72% Higher special: 100%	610 EUR **	N/A	calendar year	EEA (excl. Croatia) + UK	directional	1142 EUR***
Norway	Standard: 64% Serious contagious diseases: 100%	205 EUR**	N/A	calendar year	avg. of 3 lowest countries	direct	11480 NOK**
Panel B: Consumption based							
Sweden	901–1700 SEK: 50% 1701–3300 SEK: 75% 3301–4300 SEK: 90% 4301 SEK: 100%	194 EUR **	900 SEK**	calendar year	N/A	N/A	21500 SEK**
Denmark	0–480 DKK: 0% 480–1165 DKK: 50% 1165–2730 DKK: 75% > 2730 DKK: 85%	Only for chronically ill after 472 EUR **	480 DKK**	continuous 12 month period	N/A	N/A	11447 DKK***

Notes: Reimbursement (%) = Different reimbursement categories and reimbursement classes; Annual out-of-pocket ceiling = Annual limit for out-of-pocket expenditures; Out-of-pocket threshold = Threshold for out-of-pocket expenditure; Time period for annual ceiling = Time window where the out-of-pocket annual ceiling contributes; Reference countries (2012) = Countries that are used in external reference price calculations; * : 2005, ** : 2006, *** : 2007. Annual reimbursement expenditures are expressed in millions. Sources: PPRI, KELA (The Finnish Social Insurance Institution) and Leopold, Vogler, Mantel-Teeuwisse, Joncheere, Leufkens, and Laing (2012).

formulas transmit changes in pharmacy purchase prices to pharmacy retail prices.

Norway is a slight exception because the institutional setting allows pharmacies to charge a lower markup than what the formula presented in Table B.3 would yield.

Physician and pharmacy incentives. In some institutional settings physicians and pharmacists may have direct economic incentives to prescribe and dispense products that yield gains to them, but this is not a relevant concern in the case of the Nordic pharmaceutical markets. With respect to physicians, Sweden is the only country in our sample that had physician incentives for prescribing generics in place (PPRI 2007c). These incentive programs were regional, because in Sweden each county there is a pharmaceutical committee that drafts annual list of first choice medications for common diseases. Physicians are rewarded bonuses if they adhere to the first choice medication list, but there were no sanctions for not following guidelines (PPRI 2007c). Finland, Norway and Denmark did not use direct economic incentives to influence physician prescribing during our sample period (PPRI 2007b, 2007a, 2008).

Pharmaceutical firms can influence physician behaviour through advertising and detailing. These practices are legal in all Nordic countries, but advertising and detailing activities are monitored and regulated (PPRI 2007b, 2007a, 2008, 2007c). Detailing and advertising have the potential to influence the performance

Table B.3: Pharmacy Retail Price Formulas

Effective Period	Type	Register Price
	Denmark	
	Prescription drugs (DDK)	
26/03/2004 - 21/03/2007	<= 30	PPP + 0.61×(0.6×PPP+1.8 DKK)
	30-60	PPP + 0.61×(0.4×PPP+7.8 DKK)
	> 60	PPP + 0.61×(0.2×PPP+19.8 DKK)
	Finland	
	Prescription drugs (€)	
	0-9.25	1.5 × PPP + 0,50 €
	9.26-46.25	1.4 × PPP + 1,43 €
1/1/2003 - 1/1/2014	46.26-100.91	1.3 × PPP + 6,05 €
	100.92-420.47	1.2 × PPP + 16,15 €
	> 420.47	1.125 × PPP + 47,68 €
	Norway	
	Prescription drugs (NOK)	
1/1/2001 - 1/1/2009	0-200	1.08 × PPP
	> 200	1.05 × PPP
	Sweden	
	Prescription drugs (SEK)	
	0-75	PPP × 1.20 + 31.25
	> 75-300	PPP × 1.03 + 44.00
15/7/2009 - 1/11/2009	> 300-6000	PPP × 1.02 + 47
	> 6000	PPP + 167.00

Notes: Effective Period = Period when the retail price formula was in use; Type = Price range where the retail price formula applies; Register Price = How list price is determined from the wholesale price.

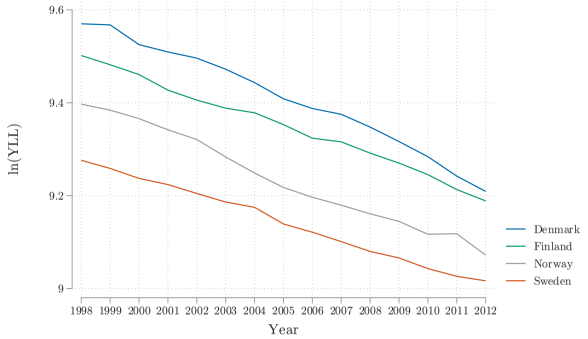
of the consumer choice reforms we study if advertising and detailing activities divert prescriptions from competitive markets to markets under patent protection. However, our results indicate that this mechanism does not play a significant role during our sample period, since in spillover analyses (Table 7 in main text) we find no increase in market sizes of the markets outside the studied choice reforms.

The pharmacy incentives come directly from the markup formulas that are regulated (PPRI 2007b, 2007a, 2008, 2007c). These formulas are presented in Table B.3. Depending on the formula structure, there might be incentives to sell cheap or expensive products. Sweden is the only country in our sample that provides an increased pharmacy markup for products that have generic competition. This change was implemented as a part of the Swedish 2009 Auction-IRP reform. There are two institutional features that limit the impact of pharmacy incentives. First, regulation in all countries states that pharmacies should substitute towards to the cheapest or to the almost cheapest drug and secondly, substitutions are done within

substitutions groups that the regulator has defined.

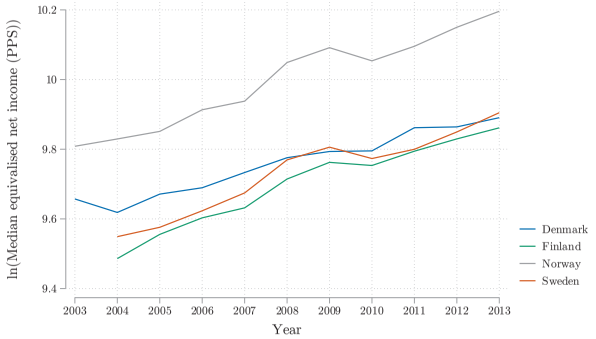
Demographic trends. Figure B.1 displays the core demographics of the Nordic countries we study. Panel B.1a displays the (log) Years of life lost from mortality (YLL) which represents how many years are lost due to premature mortality. The differences between countries are quite small and the trend is decreasing in all countries. Panel B.1b in Figure B.1 displays the median equalized net income (PPS) and panel Panel B.1c displays (log) population. Sweden is the largest Nordic country (Panel B.1c). During our observation period there are no sudden population increases in any of the examined countries. Norway is the wealthiest country (Panel B.1b). Excluding Norway, our PPS-measure evolves quite similarly in the studied countries.

Demographic trends presented in Figure B.1 show that demographics that are closely related to pharmaceutical expenditures evolve similarly in the studied countries. For some demographics there are clear level differences, but all countries share the same approximate trends during our study period. These demographic trends highlight the similarity of the countries since the core drivers of pharmaceutical demand evolve in similar fashion.



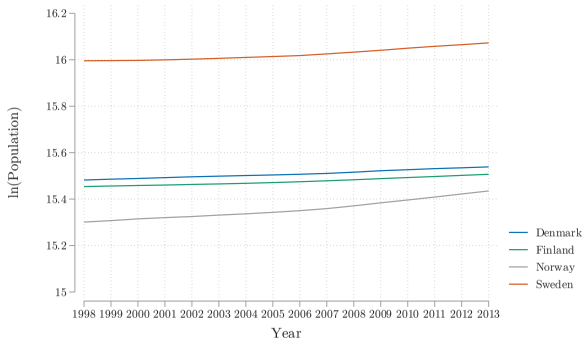
Global Burden of Disease Study 2019 (GBD 2019) Results.
Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2020.
Available from https://vizhub.healthdata.org/gbd-results/.

(a) YLL



Eurostat (2023). Mean and median income by age and sex - EU-SILC and ECHP surveys (ILC_DI03).
European Commission. Last updated April 27, 2023. Retrieved May 8, 2023
from https://ec.europa.eu/eurostat/databrowser/view/ilc_di03/default/table?lang=en

(b) ln Income



Eurostat (2023). Annual population data by age, sex, and citizenship (demo_pjan).
European Commission. Retrieved May 8, 2023
from https://ec.europa.eu/eurostat/databrowser//product/view/DEMO_PJAN

(c) ln Population

Figure B.1: Demographic Trends in the Nordics

B.2 Branded, Generic and Parallel Imported Pharmaceuticals

By origin, there can be three types of products in a given ATC5 category: The unique branded (original patented) product that was (is) protected by a patent;[28] generic products that feature the same molecule as the original drug, but are most of the time produced by different firms than the branded drug (brand manufacturers sometimes have their own generic products); and third, so-called parallel imported products, which are manufactured by the producer of the branded drug, but originally sold to a different geographic market (= EU Member State), bought there and shipped to the country in question by an intermediary company (parallel importer).

B.3 Additional Institutional Details on Regulations

Here we provide more details on the regulatory institutions regarding market entry at the European level (B.3.1), and then details for the price regulations that we study in each of the four countries in our data: Finland (B.3.3), Denmark (B.3.4), Norway (B.3.5) and Sweden (B.3.6). We close the Subsection with a discussion of minor price regulation reforms (B.3.7).

B.3.1 Relevant EU Regulations

We briefly describe the regulatory process for a given pharmaceutical product to enter an EU Member State. There are two routes: Obtaining market authorization and (after that has been granted), so-called parallel imports.

Obtaining market authorization. There are four distinct processes through which a product can receive market authorization for sale in the European common market and in EU Member States. Three of these processes, namely, the centralized, decentralized, and mutual recognition processes, are based on legislation passed by the EU. The fourth option, national market authorization, is regulated by the Member States. In the centralized procedure, authorization is granted by the European Medicines Agency (EMA) through which the authorization is valid in

28. Parallel imports may take place while patent protection is in place.

the European Economic Area (EEA).[29] In the decentralized process, a company simultaneously applies for market authorization in several Member State through the national authorities, on the condition that the product has no market authorization in any Member States. The decentralized process is led by one of the Member States, and other national authorities provide assistance in the process. In the mutual recognition process, a company applies for market authorization for a product that has already been approved in at least one Member State.

Parallel imports. Parallel imports are a feature of European pharmaceutical markets. The market share of parallel imported products varies from country to country, but the possibility of parallel imports from within the EU exists in all EU Member States and banning them is illegal.

B.3.2 Stated Reform Objectives

This subsection reviews the stated objectives for each reform we study. We collect reform objectives into Table B.4. Most objectives have been obtained from official law proposals or ministry documents. We use published research on the reforms as the source material for reform objectives when government proposals were written without explicit explanations on why a given reform needs to be implemented.

Table B.4 displays reform objectives by reform. All reforms are motivated by cost savings, but some have also non-financial objectives. If we compare our results presented in the main text to the objectives presented in Table B.4 we see that only Finnish 2009 GS $\rightarrow$ IRP, Norwegian 2005 GS $\rightarrow$ SP and the Swedish 2009 IRP $\rightarrow$ Auction-IRP reforms might have achieved their stated objectives. The success of the Swedish 2009 IRP $\rightarrow$ Auction-IRP reform is a borderline case since we don't find any increases in availability during our follow-up period. Other studied reforms have at least partially not met their objectives since either the goal for reducing expenditure or the goal of decreased prices has not been met.

B.3.3 Finland

Up to March 2003: VGS. Throughout the 1990s, the Finnish VGS required prescribing physicians to actively opt-in to allow GS to occur. In practice, GS and

29. The EEA covers the EU Member States and Iceland, Liechtenstein, and Norway.

Table B.4: Reform Objectives

Reform	Reform Objective
Finland 2003	Promote cost-effectiveness Increase market efficiency Decrease expenditure
Finland 2009	Reduce expenditure on pharmaceuticals Reduce regulatory burden on generic markets
Denmark 2000	Courage firms not to set prices above prices in Western-Europe Decrease expenditure
Denmark 2005	Decrease expenditure
Norway 2005	Savings through demand side cost sharing Stimulate price competition between brand-name and generic firms Decrease expenditure since previous Index Price policy did not generate enough savings
Sweden 2009	Increase availability Decrease expenditure Increase service standards Competence and safety in pharmaceutical supply Use pharmacies to promote efficient use of pharmaceuticals

Notes: Reform objective sources : Finland 2003 = Government proposal HE 165/2002 vp; Finland 2009 = Government proposal HE 100/2008 vp; Denmark 2000 = Ministry of the Interior and Health reimbursement system report Medicintilskud og rigtig anvendelse af lægemidler; Denmark 2005 = See paper by Kaiser, Mendez, Rønde, and Ullrich (2014); Norway 2005 = See papers by Brekke, Canta, and Straume (2022) and Brekke, Grasdal, and Holmås (2009); Sweden 2009 = Government proposal 2008/09:145

prescription of generics was almost non-existent.[30]

April 2003–March 2009: GS. The Finnish government adopted mandatory GS in April 2003.[31] In the new regime, pharmacies were required to stock one of the products at or close to the cheapest price.[32] The reimbursement of a consumer was not affected if she decided against substitution; the monetary incentives to substitute were small in drug categories with high reimbursement rates. Unlike Finland, other countries combined substitution policies with financial incentives for the patient. After 2009 GS continued to be applied for non-reimbursed and parallel imported products.

April 2009– : IRP. To address the incentive problems related to GS and high reimbursement rates, Finland adopted IRP in April 2009.[33] Reference pricing was

30. See the government proposal HE 165/2002 vp, page 6.

31. See 80/2003 §57b.

32. Pharmacies were required to offer substitution if the prescribed product was either 2€(retail price less than 40€) or 3€(retail price more than 40€) more expensive than the cheapest product in the substitution group.

33. See Chapter 6 §18-§23.

applied to products that were publicly reimbursed and for which at least one generic substitute was available. The highest reimbursed retail price in a substitution group is the reference price. During our sample period, the reference price was defined as the cheapest retail price within the reference price group + 1.5€ (retail price less than 40€) or + 2.5€ (retail price greater than 40€). Reference prices were updated quarterly. If the price exceeds the reference price, the consumer is reimbursed on the basis of the reference price and pays the price difference out of pocket. Parallel imports were not included in the system until 2017.[34]

In addition to the above major reforms, Finland has implemented minor reforms in the 2000s. The first minor reform in 2006 imposed that the price cap for new entrants should be 40% lower than the cap of the original product. The second reform was a 5% price cap cut on all reimbursement drugs. These minor reforms are explained in more detail in Online Appendix Section B.3.7.

B.3.4 Denmark

May 1997–Oct. 2000: IRP. In 1997, Denmark adopted mandatory substitution of generics on top of an existing RP system for generics.[35] This regime corresponds to our definition of an IRP system. The Danish system required pharmacies to substitute to the cheapest interchangeable available product unless the price differential was (roughly) less than 5%.[36] The prescribing physician could still opt out of substitution for medical reasons. If a consumer did not buy the reference-priced product, she was required to pay the price difference between the products out of pocket.

Nov. 2000– Dec. 2004: ERP. Denmark switched from IRP to ERP in November 2000. Reference prices were calculated using prices in other European countries.[37] If a product was sold only in Denmark or the domestic price was lower than the price calculated using the other European prices, the price in Denmark

34. See 1100/2016 Chapter 6 §18. Before this, parallel imports could be included in reference price groups if other generics were on the market. After the 2017 change, this requirement was lifted. In practice, this allowed RP to start even during the patent period.

35. See BEK nr 308 af 06/05/1997 §36–§37.

36. This "price corridor" in Denmark has remained mostly the same since 1996. See BEK nr 724 af 01/08/1996 §37.

37. EU-15 excluding Greece, Luxembourg, Spain, and Portugal.

was used as the reference price.

The implementation process of ERP on the Danish market had already started in 1998 when manufacturers of new pharmaceutical substances (defined by market entry after April 1, 1997) were required to inform the Danish government of their prices in other European countries.[38] The process was finalized in November 2000 when the Danish government stopped the reimbursement of all products that exceeded their European average prices.[39] While the use of ERP was included in the legislation in summer 2001, the regulator started applying ERP already in November 2000.[40] We use November 2000 as the date of the reform.

Jan. 2005– : IRP. ERP lasted until April 1, 2005, when it was replaced by IRP.[41] In the new regime, the reference price was again the lowest domestic price within a substitution group. The government also abolished the ERP of patented pharmaceuticals.

There are two other institutional changes that occur in Denmark during our study period that are not directly related to the reforms studied. The first is the overhaul of the reimbursement system. In March 2000, the Danish government adopted a new reimbursement model in which the fixed product-specific reimbursement level was replaced by a system in which the patient's reimbursement level was non-linearly calculated based on spending (see Simonsen, Skipper, Skipper, and Christensen 2021). The other change is a price freeze agreement between the Danish government and an association of pharmaceutical manufacturers. We explain these changes in more detail in Online Appendix Section B.3.7.

38. The government would then use this price information to cap the public reimbursement to the average of the two lowest prices.

39. As stated in LOV nr 1031 af 23/11/2000 §7j.

40. See LOV nr 495 af 07/06/2001 §7d.

41. See LOV nr 1431 af 22/12/2004 §7d.

B.3.5 Norway

March 2001–2005: GS. Norway adopted a GS policy and liberalized the pharmacy sector in 2001.[42] Prior to the 2001 reform Norway had an ERP system.[43] Thus, the GS system with ERP elements is the baseline regulatory regime for subsequent reforms in Norway.

If the consumer did not substitute to the cheapest alternative in that regime, she had to pay the difference in price between the cheapest alternative and the chosen product out of pocket.[44] The Norwegian GS did not explicitly require pharmacies to substitute with a cheaper alternative; instead, pharmacies were incentivized to offer GS. Originally, if pharmacies sold a product whose wholesale price was below the maximum wholesale price, they could keep 50% of the difference between the retail price and the maximum retail price. See FOR-2001-12-17-1537 §12-3. Generic alternatives received the same maximum pharmacy purchase price as the original manufacturer. The difference was calculated from the product's maximum wholesale price with the maximum retail markup and the actual retail price, which was also subject to the maximum markup rule. Between 2003 and 2005 eight active ingredients were subject to IRP (called the index price). These active ingredients are excluded from our estimation sample for the Norwegian 2005 IRP → SP reform; for a review of the index price system, see Brekke, Grasdal, and Holmås (2009) and Brekke, Holmas, and Straume (2011).

Jan. 2005– : The Step-Price regime. Norway implemented a major change to the GS system in 2005 by introducing the current SP system. After generic entry has taken place, the maximum reimbursement price (now called the Step-Price) gradually decreases.[45] The base level for the price is established as the maximum allowed retail price at the time of generic entry. If a consumer decides not to buy the product priced at the Step-Price, she is required to pay the difference in price out of

42. We do not study the effects of this substitution reform because the effects of the reform cannot be separated from the effects of pharmacy market liberalization. For further information, see LOV-2000-06-02-39.

43. The maximum reimbursement price was the average of the three lowest prices of the original patented product in the other EEA countries.

44. In comparison to the Finnish GS, the Norwegian regime provided financial incentives while the Finnish policy did not. See LOV-2000-06-02-39 for further information.

45. The Norwegian Medicines Agency determined when generic entry has taken place. In practice, it requires that the generic product be available in pharmacies.

Table B.5: The Step Price Schedule

Starting from	Step-Price Calculation				
01/01/2005	**<100 Mill. NOK 12 months before**		**>= 100 Mill. NOK 12 months before**		
	1. Generic competition	-30%	1. Generic competition	-30%	
	2. 6 months after	-40%	2. 6 months after	-50%	
	3. 12 months after	-50%	3. 12 months after	-70%	
01/01/2007	**<100 Mill. NOK 12 months before**		**>= 100 Mill. NOK 12 months before**		**Cut rate**
	1. Generic competition	-30%	1. Generic competition	-30%	**Simvastatin** -85%
	2. 12 months after	-55%	2. 12 months after	-75%	
	3. Final cut if sales >100 Mill. NOK	-85%	3. Final cut if sales >100 Mill. NOK	-85%	

Notes: This table provides the two first Stepped Price rules from Norway. The starting price for calculating the Stepped-Price is the price cap of the original at the start of generic competition. See FOR-2004-12-17-1712 and FOR-2006-12-01-1327 for further details.

pocket. The first price cut occurs at the beginning of generic competition, followed by further cuts after 6 months and 12 months.[46] The magnitude of the price cuts is related to the total sales prior to generic entry: During our sample period, the first price cut was 30%, the second between 40–50%, and the third between 50–70%.[47] The Step-Price acts as a reference price whose future development is known and fixed by the government. The reform also required pharmacies to keep at least one product at or below the reference price in stock.

Step Price-IRP Schedule. Table B.5 shows how the SP regulation worked during our observation period. SP regulation uses predetermined rules to set the price where reimbursement is paid, instead of competition determining the reimbursement price. The price formulas for SP regulation start from the onset of generic competition, and the formula depends on the size of the market before the generic competition started. Table B.5 also shows that the steps of price decreases change over time. In the price formulas valid from January 1, 2005, the largest price decrease was 70% but this was changed to 85% starting January 1, 2007.

B.3.6 Sweden

Nov. 2002–2009: IRP. Sweden adopted IRP in November 2002.[48] The system required pharmacies to substitute the prescribed product with the cheapest

46. Appendix Section B.3.5 shows the price cut timing in the Step-Price system.

47. See FOR-2004-12-17-1712.

48. See Lag (2002:160) om läkemedelsförmåner m.m. §21. Before 2002, Sweden used IRP without GS. In practice, this meant that the government issued mandatory price decreases as a function of the lowest price of substitutable products.

substitutable product available unless the prescribing physician had opted out of the substitution. Unlike other Nordic countries, patients were reimbursed only for the prescribed product or the product to which the pharmacy offered substitution: This means that if a patient wanted to buy another product (without the decision of the prescribing physician), she would pay the full price (not the price difference between the chosen and the cheapest product) out of pocket. A notable factor in the Swedish GS system was the fact that all pharmacies in the country were operated at the time by the government-owned monopoly Apotek Ab until 2009, when the pharmacy sector was liberalized.

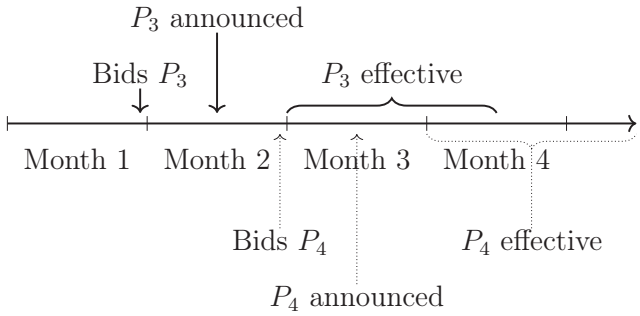
Dec. 2009– : Auction-IRP. Following the liberalization of the pharmacy sector in 2009, a new interpretation of the law was adopted: The cheapest product would be determined at the national level. This led to the establishment of the current "Product of the Month Auction" system, where pharmaceutical manufacturers issue monthly prices (bids) within a given package size and a substitution group. Winners are called products of the month. Consumers can in practice only choose between the prescribed product and the product of the month, although for the first two weeks of each month, the legislation allows pharmacies to also substitute to the winning product of the previous month. The winner and the previous winner thus have high market shares. The government also declares secondary and third alternatives to the winner in case the winner has supply problems.

During our sample period, Sweden also implemented minor price regulation reforms that are related to price caps and the mechanics of the Auction-IRP system. Price caps were subject to one-time cuts in 2009, and later price cap rules within substitution groups were changed.[49] The Auction-IRP system was reformed in 2011 by redefining substitutable products, and in 2012 the backup winners were included in the regulation. These minor reforms are explained in Appendix Section B.3.7.

Auction-IRP timing. Figure B.2 shows how auction timing works in the Auction-IRP regime. Bids for prices are submitted before they become effective. If a bid is submitted during Month 1, the bid is revealed to all participants during Month 2, and the price is effective during Month 3. Another important feature of the timing of the Auction-IRP is that winning the auction provides benefits

49. It important to note, that the Swedish Pharmaceutical industry proposed the 2009 price cut to regulator.

Figure B.2: Auction-IRP Timing



only for one month at a time. Regulation allows the previous month's winning product to be dispensed two weeks into the month. This is represented by the curly brackets denoting the effective prices in Figure B.2.

B.3.7 Minor Price Regulation Reforms

During the periods of our estimation samples, Nordic countries implemented reforms that we categorize as minor. These reforms create changes, e.g., in the way pharmaceuticals are priced and reimbursed.[50] We have collected the minor reforms into Table B.6: There are two minor reforms in Denmark, two in Finland, one in Norway, and four in Sweden during our observation periods.

Denmark. During our sample periods, the Danish regulator made price cap or price "freeze" agreements with pharmaceutical firms represented by the Danish Association of the Pharmaceutical Industry Danish Association of the Pharmaceutical Industry (LIF-DEN). Not all firms present in the Danish market are represented by LIF-DEN, and this leads to a situation where price caps were not imposed on all products. In these agreements, the Danish regulator and the firms agree that a market price from a certain date acts as the price cap for a period of time. These price agreements were in place during our observation periods.[51]

50. Changes in the reimbursement rates, reimbursement ceilings and OTC deregulation policies (pricing and distribution) are excluded from the table. OTC-deregulation policies are excluded because we study prescription drugs.

51. Price cap agreement signed on 19.3.2019 states that the first price cap agreement was signed

Table B.6: Minor Price Regulation Reforms in the Nordics 2001-2012

Country	Year	Reform Type	Studied Reform(s)
Denmark	2000–	Reimbursement system overhaul	Denmark 2000
Denmark	2001–	Price freeze agreements suggested by industry	Denmark 2000, 2005
Norway	2003–2004	IRP for 8 active ingredients	Norway 2005
Finland	2006	5% Price cap cut for reimbursed products	Denmark 2005, Norway 2005
Finland	2006–	Price cap rule for generic entrants	Norway 2005, Finland 2009
Sweden	2009	Mandatory price cap cut & pharmacy margins	Sweden 2009
Sweden	2010–	Substitution group redefinition & back-up products	Sweden 2009
Sweden	2011–	Mandatory price caps in substitution groups	Sweden 2009
Sweden	2012	Back-up winners in Auction-IRP system	Sweden 2009

Notes: Country = Country where the minor reform happened; Year = When the minor reform happened; Reform Type = Minor reform type; Studied Reform(s) = Reforms that are studied in the paper, where the minor reform happens during the sample period.

In March 2000, the Danish government adopted a new reimbursement model where the fixed product-specific reimbursement level was replaced by a system where the patients' reimbursement level was a non-linear function of spending (see Simonsen, Skipper, Skipper, and Christensen 2021). This reimbursement system change happens in the pre-period of the Danish 2000 reform. The reimbursement reform gave incentives to persons who already exceeded their annual pharmaceutical cost limit to stock pharmaceuticals, because after the reform they faced 100% coinsurance. We see this effect as a pre-period increase in quantity in Figure B.9a where the outcome is quantity. The change in the reimbursement system does not affect average expenditure because pricing did not respond to the change.

Finland. In 2006 Finland implemented two minor reforms related to pharmaceutical pricing. The first reform was a 5% price cap cut for reimbursed pharmaceuticals, and the second was the price cap rule for generic products. The price cap cut reduced the maximum price of the reimbursed product and led to a decrease in wholesale and retail prices for the products for which the price cap was binding.[52] These price cuts could influence the evaluation of the Danish 2005 IRP $\rightarrow$ ERP and the Norwegian IRP $\rightarrow$ SP reforms, because we use Finland as the control group. We deal with this issue by constraining the sample period to

in 2006, but working paper version of Kaiser, Mendez, Rønde, and Ullrich 2014 mentions that the price agreements between LIF-DEN and the Danish government were already implemented in 2001. This means that some form of price controls exist also in the Danish market almost throughout the whole time period we use Danish data in our analyses.

52. See 885/2005 for additional details.

the time before the price cut. We present results where the sample period is not constrained by the price cut in Appendix Section B.9.

The second Finnish reform in summer 2006 was the formalization of how price caps of the generic entrants are calculated when the first generic product enters. This reform formalized that generic products are accepted into the reimbursement system only if they are priced at least 40% lower than the cap of the originator product. If a company does not accept this proposed cap, the product can enter the market, but it is not eligible for public reimbursement. This regulation change does not complicate our empirical analyses like the implemented price cut, because the markets we study had generic entry before our observation period.

Norway. The only minor change in price regulation in Norway during our sample period was the IRP-experiment (Index-Price) for eight active ingredients (=ATC5 categories). This policy was in place 2003–2004. The Index-Price policy was an IRP variant similar to the Finnish 2009 policy.[53] This means that the Index-Price policy change occurs during the pre-period of the SP reform. To ensure that all treated markets have the same pre-period regulation regime, we discard the markets where index-price regulation was implemented. Brekke, Grasdal, and Holmås (2009) report that the Index-Price policy was shut down because the policy did not achieve the desired amount of cost savings and price reductions.

Sweden. The minor reforms in Sweden are related to Auction-IRP reform implementation, (re)definition of back-up winners in Auction-IRP regulation and price cap changes. The Auction-IRP reform was a package of four regulatory changes that were implemented before and after the start of the monthly auctions. The reform cut mandatory price caps, changed pharmacy margins, redefined substitution groups and specified the use of back-up products in the case of supply problem. In addition, Sweden changed how price caps are formulated and tweaked the Auction-IRP reform back-up product selection criteria during our sample period.

Sweden introduced a mandatory one-time price cap cut for off-patent products

53. the index price at producer price (so-called GIP) level was calculated as the total turnover value for all products in the index price group for the period, divided by the total quantity sold during the period. The index price was determined at the producer level (GIP), to which a 10% maximum profit was added for the benefit of the wholesalers. The final index price was obtained by adding the maximum pharmacy mark-up to the index price at the PPP (pharmacy purchase price) level. The final index prices were in PRP (pharmacy retail price). See Brekke, Holmas, and Straume (2011) and Brekke, Grasdal, and Holmås (2009) for more details.

in markets with substitutable products and generic competition in July 2009 as a part of the Auction-IRP reform package (Bergman, Granlund, and Rudholm 2016).[54] The unique feature of this price cut is that it was proposed by the Swedish Association of the Pharmaceutical Industry (LIF-SWE), the trade association for the research-based pharmaceutical industry in Sweden.[55] Prices of off-patent products were capped at 35% of the price of the originator product that prevailed 12 months before the expiration of the patent.[56] The price cap decrease was planned so that after the price cut the originator price cannot be lower than the cheapest comparable generic product. Price caps were implemented if three conditions were met: i) An identical generic product must have been sold at a price below 30% of the price during patent protection by a firm that achieved at least 10% of sales within the substitution group; ii) there must have been positive generic sales for at least 4 months; and iii) at least 6 months must have passed since generic competition was first established in the exchange group. Only when all three conditions are met the new price cap becomes effective (Bergman, Granlund, and Rudholm 2016).

In addition to the 2009 mandatory one-time price cap cut for off-patent products, the Auction-IRP reform package contained three other minor regulatory changes (Bergman, Granlund, and Rudholm 2016). In October 2009 pharmacy retail margins for products that have a substitution group were increased by 10 SEK (approximately one euro). The substitution group definition was changed in February 2010, because before the 2009 IRP → Auction-IRP reform substitution groups were defined with respect to the prescribed article. A substitution group contained all products with the same active ingredient, strength, form and package sizes that deviated no more than 12% of the prescribed article. After 2010 the substitution group redefinition regulator pre-defines substitution groups with fixed package size limits (Bergman, Granlund, and Rudholm 2016). The last minor regulation change attributed to the 2009 IRP → Auction-IRP reform was the possibility to dispense the second or third cheapest product if a national stock-out

54. See The price cut announcement for additional details.

55. The Swedish price cut resembles the Danish price freeze agreements that are based on the negotiations between pharmaceutical industry and the government.

56. For products that experienced patent expiration before October 2002, the price cut is either calculated from the price that was applied on September 2001 or from the price that was applied 12 months before the patent expiration.

occurs. This change was implemented in May 2010.

Outside the changes related to the Auction-IRP reform implementation, price cap regulation was changed in 2011 and the new price cap regulation contains two distinct phases.[57] In the first phase, generic competition has not started within a substitution group and the price cap is defined as the maximum price in the substitution group. This price cap is defined as the initial price cap. In the second phase, the price cap decreases are triggered by (generic) competition. Mandatory price caps were imposed if four months had passed since generic competition had started and at least one product within the substitution group is priced 30% lower than the initial price cap. When these conditions are met, the price cap for all products in the substitution group is reduced by 35% of the initial price cap. This regulation change meant that a decrease in the price of one product triggers a decrease in the price cap for all products in the substitution group.

In 2012 Sweden changed the Auction-IRP regulation to allow multiple winners in the auction.[58] The reason for the change was to allow pharmacies to substitute with backup products (the second or third cheapest product in the auction) if the auction winner has problems supplying the market. Before this change, the regulator could announce a national stock-out of the cheapest product (procurement winner) after which the pharmacies were allowed to sell the second or third cheapest generic drug (Bergman, Granlund, and Rudholm 2016).

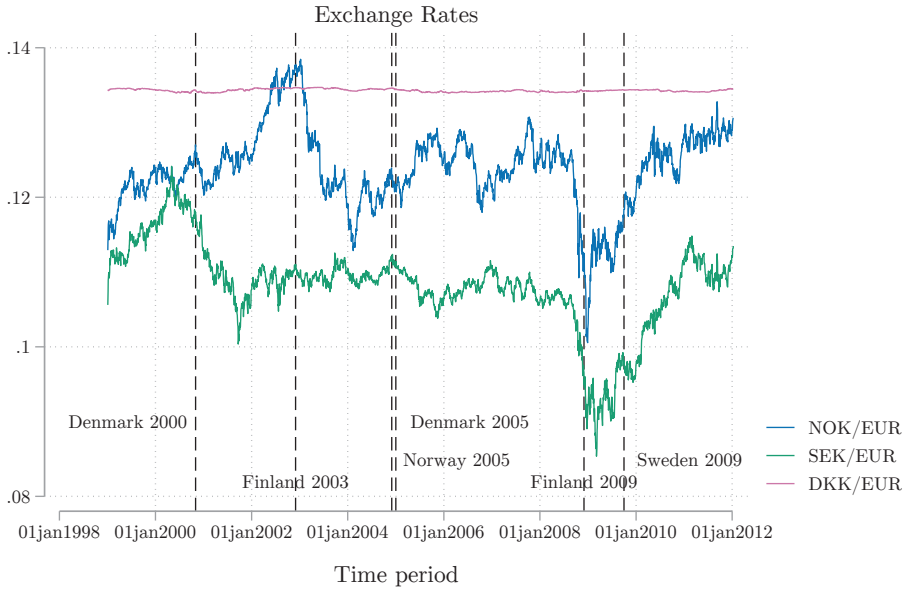
B.4 Exchange Rate Shocks

We use domestic currencies in our analyses. The rationale for this is that sudden changes in exchange rates can bias our results. This is illustrated in Figure B.3 which plots the NOK–EUR, SEK–EUR and DKK–EUR exchange rates and the start dates of the reforms we study.

Figure B.3 shows that the DKK–EUR exchange rate evolves differently from the two other exchange rates. This follows from the fact that during the study period, the Danish Krone (DKK–EUR) is linked to the Euro. It is evident from the figure that some reforms start close to sudden and extreme changes in the exchange

57. TLVFS 2009:4
58. TLVFS 2009:5

Figure B.3: Exchange Rate Shocks



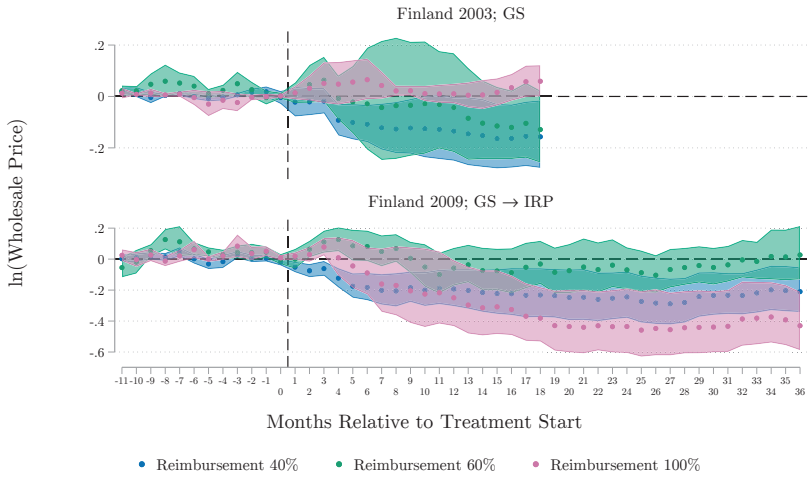
Data source: European Central Bank.

rate, such as the Swedish 2009 IRP → Auction-IRP reform. The 2009 fluctuations in exchange rates were induced by the global financial crisis. If the analyses were done using outcomes converted to the same currency, the exchange rate movements would influence the results because our differences-in-difference specifications could not to separate exchange rate movements from reform effects.

B.5 Reimbursement Rates and the Finnish 2003 (VGS→GS) and 2009 (GS→IRP) Reforms

The main text presented results for the Finnish 2003 VGS → GS and 2009 GS → IRP reforms. The results showed quite clearly that the 2009 GS → IRP reform was much more effective than the VGS → GS reform of 2003 in reducing pharmaceutical expenditure. The main explanation for this difference is that in the 2003 VGS → GS reform consumer choices did not influence the reimbursement consumer received. This meant that a consumer with full reimbursement (100%) had no incentive

Figure B.4: Finland 2003 and 2009 by Reimbursement Status



Estimator: Callaway and Sant'Anna (2020). 9999 replications for ATC-5 wild bootstrapped standard errors. Denmark used as a control group. Outcome data source: DLI-MI and FIMEA.

to substitute to cheaper products. The 2009 GS → IRP reform tied consumer reimbursement to the cheapest products in the substitution group, giving consumers an additional incentive to substitute to cheaper products. In this Subsection, we examine how the effects of regulation depend on the reimbursement rate.

The upper part of Figure B.4 shows the results for the 2003 VGS → GS reform and the lower part for the 2009 GS → IRP reform. Both panels present results for products facing one of the three reimbursement rate sub-samples (40%, 60% and 100%).[59]

The top panel of Figure B.4 clearly shows that the negative price effect is driven by products with the 40% reimbursement rate, because the treatment effect for higher rates is zero. These results help to rationalize why the 2003 VGS → GS reform delivered only modest savings. Average expenditure did not decrease much because product prices did not respond to the reform in all reimbursement categories. The bottom panel of Figure B.4 shows that in the 2009 GS → IRP reform, all reimbursement categories show decreasing prices due to the reform.

59. These sub sample regressions are estimated using product specific data instead of market level data as in the main analysis. This change helps to show whether incentives related to reimbursements explain the differences between the two reforms or not.

These price results are also in line with the expenditure results shown along the main results. Average expenditure substantially decreased with the GS → IRP reform, and part of the explanation for the decrease is that the average price in all categories decreased due to the reform.

B.6 The Finnish 2009 GS → IRP and the Swedish 2009 IRP → Auction-IRP Reforms: Alternative Control Groups

As mentioned in the main text, for the Finnish GS → IRP and Swedish 2009 IRP → Auction-IRP reforms we have the possibility to use either Norway or Denmark as control groups. Here we report the results of this exercise. We summarize our results by estimating ATTs (see Table B.7) and illustrate how reform effects evolve over time by estimating event study regressions.

We find that main results presented in Table B.7 are qualitatively the same regardless of the used control group. There are some differences in estimate sizes, but almost in all cases the point estimates from the model with the alternative control group fall within confidence intervals of the original estimates. The most notable exception is the Finnish 2009 GS → IRP reform (presented in Figure B.5) where the results using Denmark as a control group yield larger absolute effects when Expenditure per Dose is used as the outcome variable.

Table B.7: Average Treatment Effects (Control Group Comparison)

	Finland 2009 GS → IRP			Sweden 2009 IRP → Auction-IRP		
	NOR	DEN	NOR&DEN	DEN	NOR	NOR&DEN
Average Expenditure per Dose	-0.15*	-0.21*	-0.17*	-0.31*	-0.25*	-0.28*
	[-0.21, -0.09]	[-0.29, -0.14]	[-0.23, -0.12]	[-0.38, -0.24]	[-0.32, -0.17]	[-0.35, -0.22]
Number of Product Names	0.02	-0.01	0.01	0.04	0.06*	0.07*
	[-0.05, 0.09]	[-0.07, 0.05]	[-0.05, 0.07]	[-0.02, 0.11]	[0.02, 0.11]	[0.03, 0.11]
Average Price per Dose	-0.04	-0.11*	-0.07*	-0.15*	-0.04	-0.09*
	[-0.09, 0.02]	[-0.18, -0.04]	[-0.12, -0.01]	[-0.22, -0.08]	[-0.12, 0.05]	[-0.16, -0.02]
Number of Doses	0.04	0.03	0.03	-0.01	0.10*	0.04
	[0.00, 0.07]	[-0.01, 0.07]	[0.00, 0.07]	[-0.08, 0.07]	[0.01, 0.19]	[-0.03, 0.12]
Package-level Price per Dose	-0.11*	-0.19*	-0.15*	-0.17*	-0.06	-0.12*
	[-0.16, -0.06]	[-0.27, -0.11]	[-0.21, -0.09]	[-0.24, -0.10]	[-0.12, 0.00]	[-0.18, -0.06]

Notes: Two-way fixed effects (Denmark 2000 and 2005, Norway 2005) and Callaway and Sant'Anna (2020) (Finland 2003 and 2009, Sweden 2009). Outcome data source: DLI-MI (2007–2013), Farmastat (2004–2013), Fimea (2007–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013). Confidence intervals calculated at the 95% confidence level; * = statistically significant. 10000 replications for ATC-5 wild bootstrapped standard errors.

B.7 Event Study Results for Secondary Outcomes

In this Subsection we present event study results for our secondary outcomes (Average Price, Wholesale Price and Doses) for each reform.

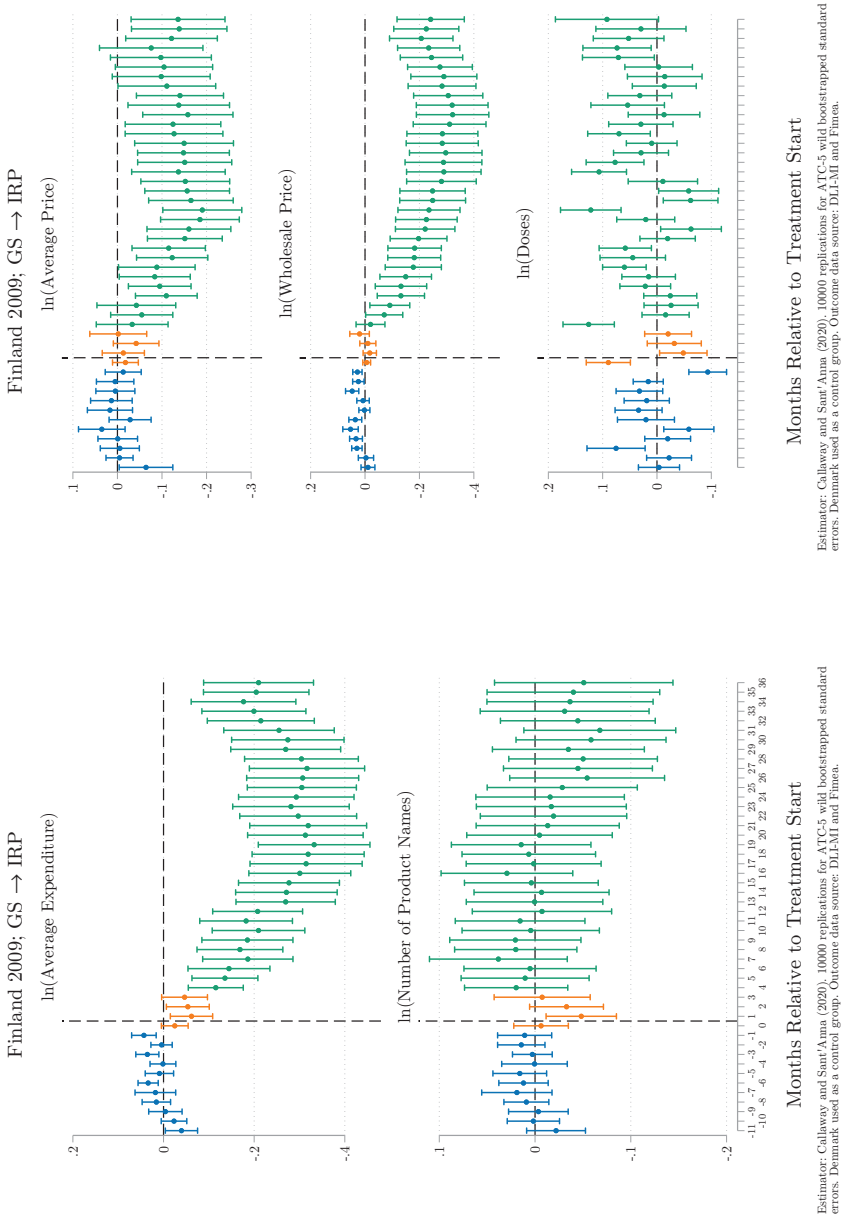
Reforms without Consumer Incentive Changes: Figure B.9 collects event study results for Danish 2000 IRP → ERP and 2005 ERP → IRP reforms. Event study results for both Danish reforms follow the same patterns as in the case of the Finnish reforms: The treatment effect is larger in absolute value when using package-level wholesale price than when using the market-level average price. The increase in quantity (Doses) for the 2000 reform is a result of the change in the Danish reimbursement system. This change had no effect on pricing, because neither price measure reacts to the change in the reimbursement system.[60]

Reforms with Small Consumer Incentive Changes: Figure B.10 collects event study results for the Finnish 2003 VGS → GS and 2009 GS → IRP reforms. The estimated treatment effects are smaller in absolute value when the outcome variable is defined at the market level than when using package level prices. It is interesting to note that when studying the Finnish 2009 reform the treatment effect converges to zero using market-level prices, but to 11% using package level prices.

Reforms with Moderate Consumer Incentive Changes: Figure B.11 collects event study results for the Norwegian IRP → SP reform. The Norwegian 2005 IRP → SP reform repeats the earlier finding that package-level prices (Package-level Price per Dose) can yield different results than the market level price (Average Price per Dose) when consumer choice reforms are studied.

Reforms with Major Consumer Incentive Changes: Figure B.12 collects event study results for the Swedish 2009 IRP → Auction-IRP reforms. We find almost identical price effect results for the Swedish 2009 IRP → Auction-IRP reform.

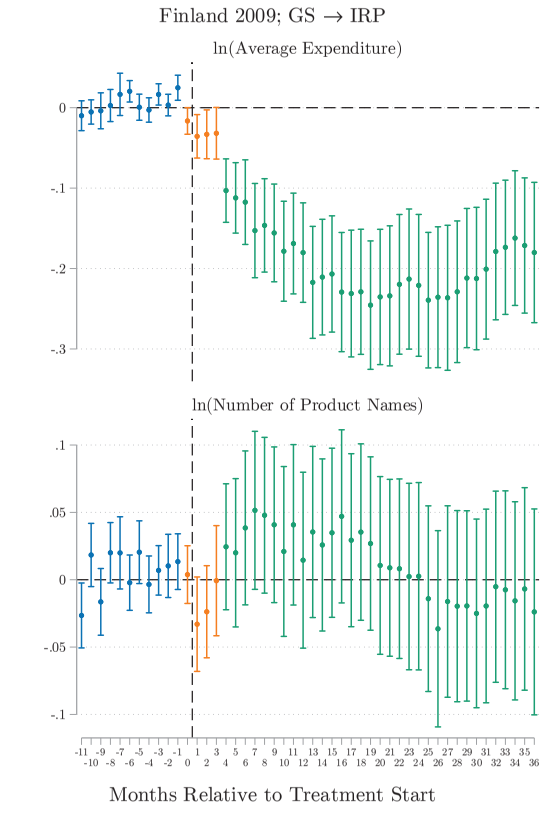
60. Appendix Section B.3.7 describes the Danish reimbursement system change in detail.



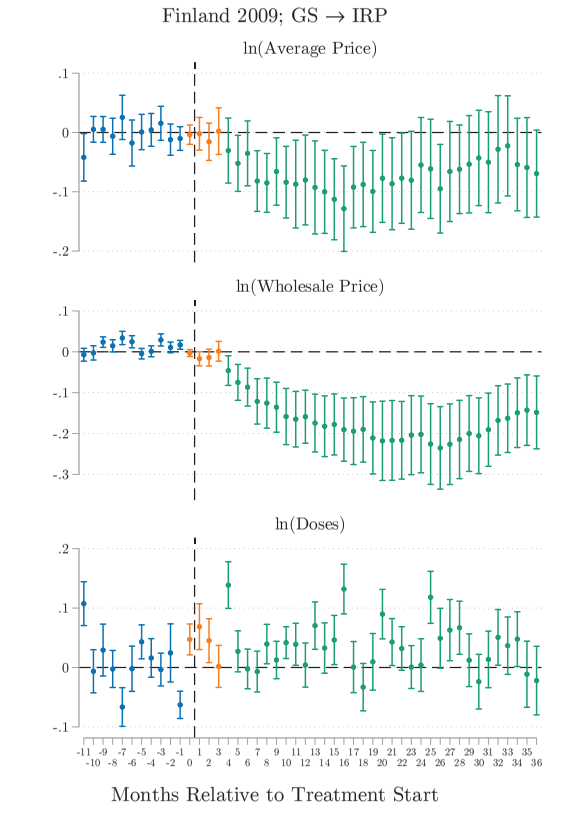
(a) Finland 2009 – Main

(b) Finland 2009 – Secondary

Figure B.5: The Finnish 2009 GS → IRP Results with Denmark as the Control Group

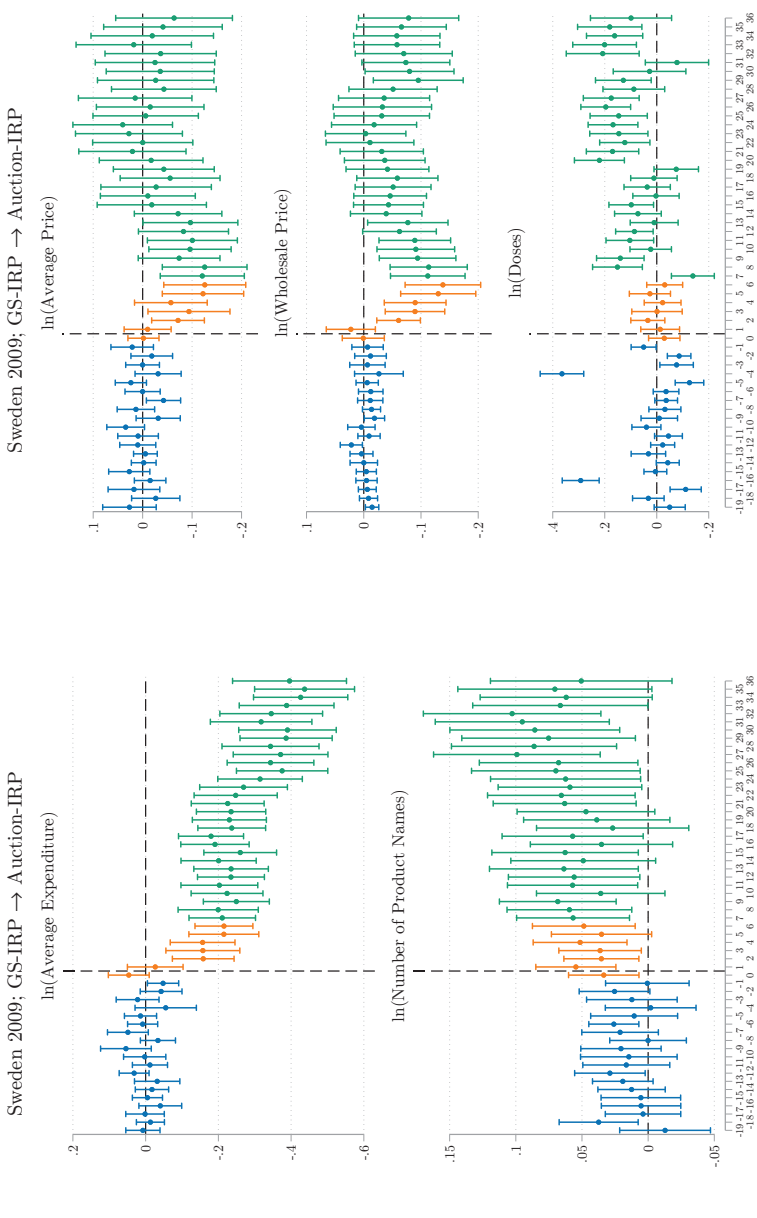


(a) Finland 2009 – Main



(b) Finland 2009 – Secondary

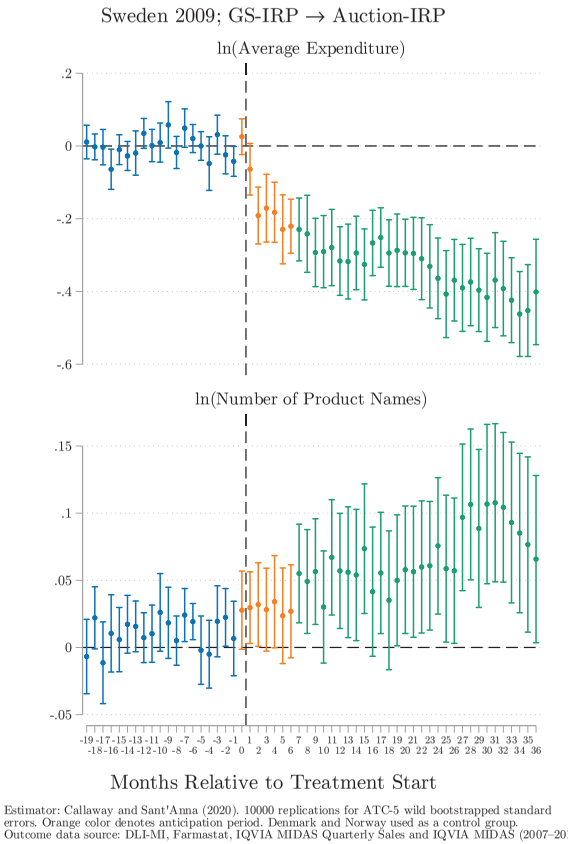
Figure B.6: The Finnish 2009 GS → IRP Results with Norway and Denmark as the Control Group



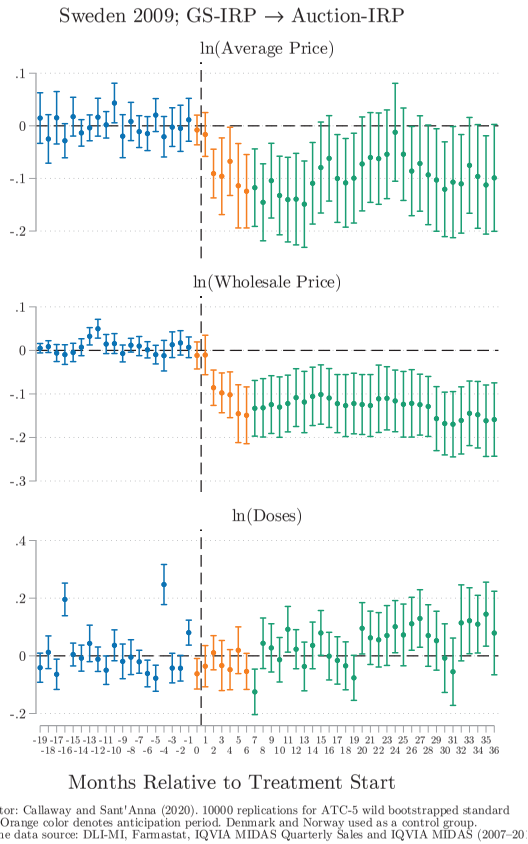
(a) Sweden 2009 – Main

(b) Sweden 2009 – Secondary

Figure B.7: The Swedish 2009 IRP → Auction-IRP Results with Norway as the Control Group

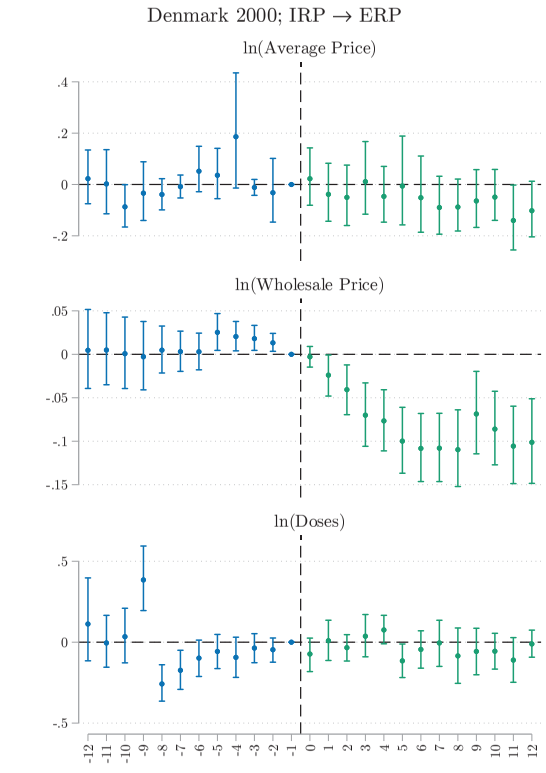


(a) Sweden 2009 – Main



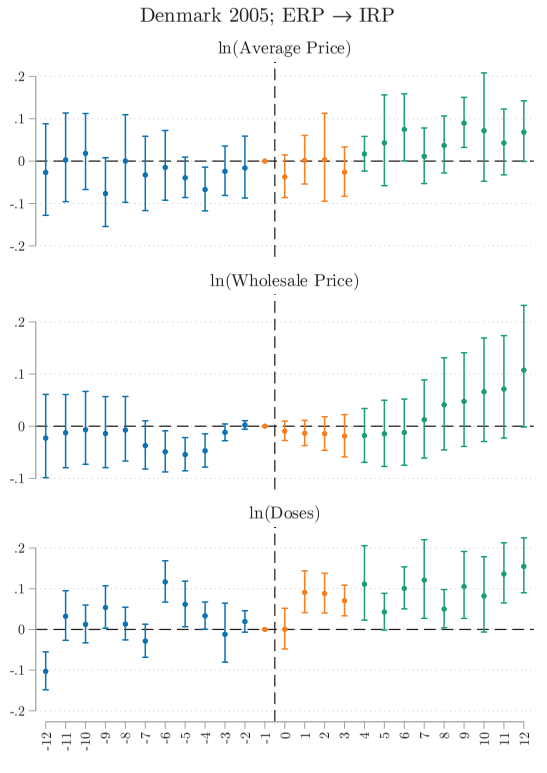
(b) Sweden 2009 – Secondary

Figure B.8: The Swedish 2009 IRP → Auction-IRP Results with Norway and Denmark as the Control Group



Estimator: Two-way fixed effects. 10000 replications for ATC-5 wild bootstrapped standard errors. Finland used as a control group. Outcome data source: DLI-MI and Fimea.

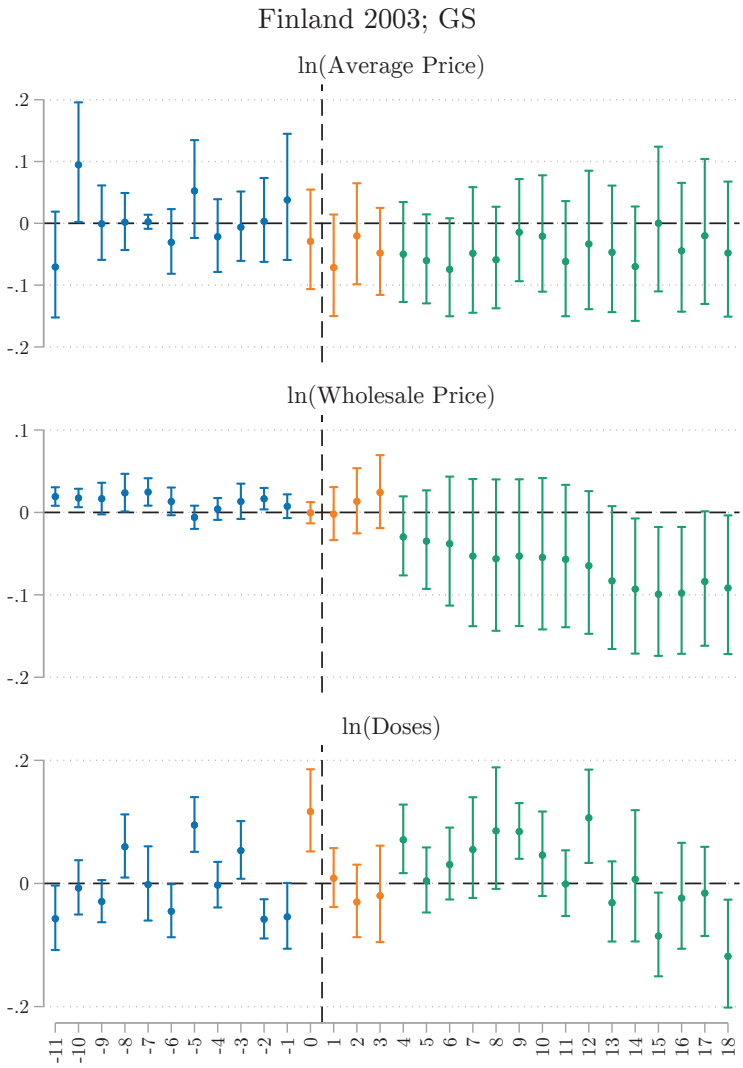
(a) Denmark 2000



Estimator: Two-way fixed effects. 10000 replications for ATC-5 wild bootstrapped standard errors. Orange color denotes anticipation period. Finland used as a control group. Outcome data source: DLI-MI and Fimea.

(b) Denmark 2005

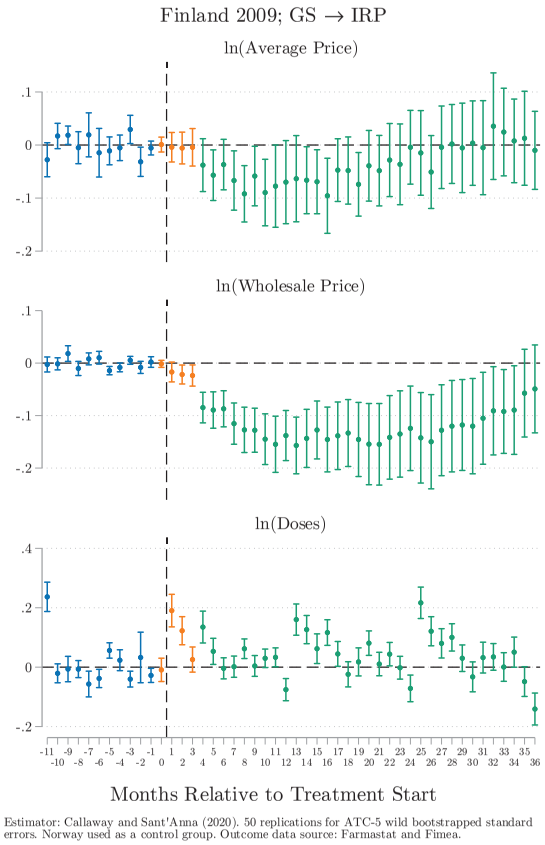
Figure B.9: Reforms without Consumer Incentive Changes: Secondary Outcome Variables



Estimator: Callaway and Sant'Anna (2020). 10000 replications for ATC-5 wild bootstrapped standard errors. Denmark used as a control group. Outcome data source: DLI-MI and Fimea.

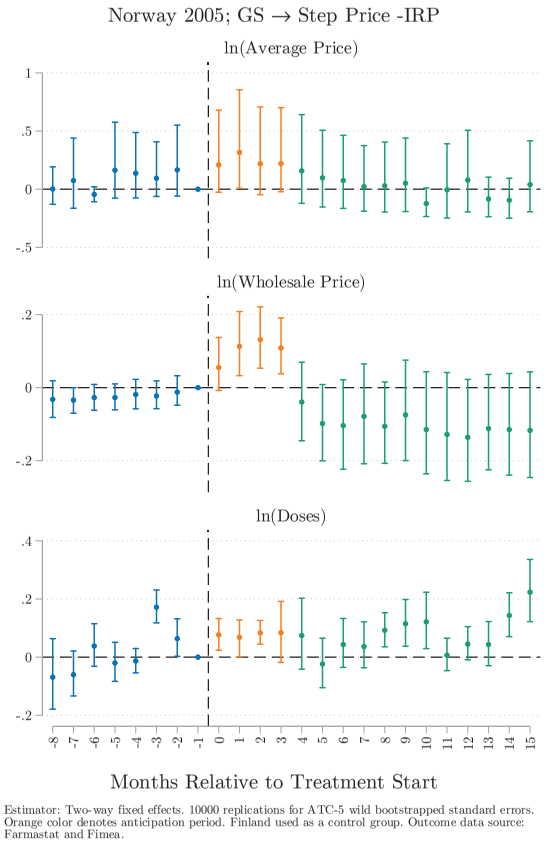
(a) Finland 2003

Figure B.10: Reforms with Small Consumer Incentive Changes: Secondary Outcome Variables



Estimator: Callaway and Sant'Anna (2020). 50 replications for ATC-5 wild bootstrapped standard errors. Norway used as a control group. Outcome data source: Farmastat and Fimea.

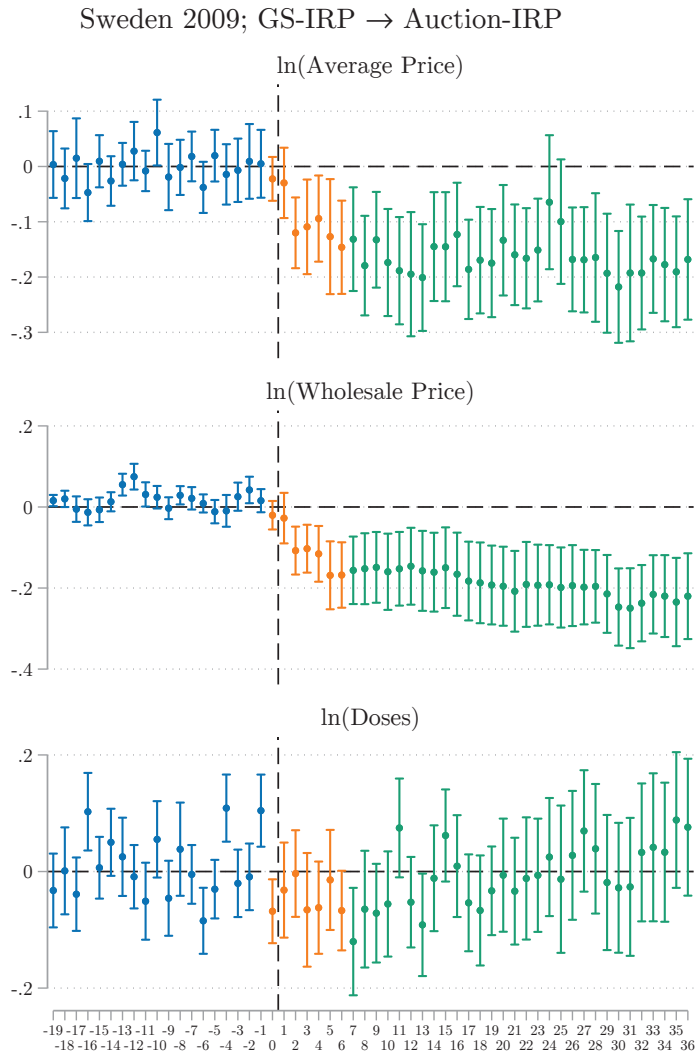
(a) Finland 2009



Estimator: Two-way fixed effects. 10000 replications for ATC-5 wild bootstrapped standard errors. Orange color denotes anticipation period. Finland used as a control group. Outcome data source: Farmastat and Fimea.

(b) Norway 2005

Figure B.11: Reforms with Moderate Consumer Incentive Changes: Secondary Outcome Variables



Estimator: Callaway and Sant'Anna (2020). 10000 replications for ATC-5 wild bootstrapped standard errors. Orange color denotes anticipation period. Denmark used as a control group. Outcome data source: DLI-MI, IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013).

(a) Sweden 2009

Figure B.12: Reforms with Major Consumer Incentive Changes: Secondary Outcome Variables

B.8 Weighted ATT Results

Table B.8: Average Treatment Effects

	Denmark 2000 IRP → ERP	Denmark 2005 ERP → IRP	Finland 2003 VGS → GS	Finland 2009 GS → IRP	Norway 2005 GS → SP	Sweden 2009 IRP → Auction-IRP
Panel A: Main Estimations						
Average Expenditure per Dose	-0.05*	0.04	-0.04	-0.15*	-0.21*	-0.31*
	[-0.09, -0.01]	[-0.01, 0.09]	[-0.09, 0.01]	[-0.21, -0.09]	[-0.29, -0.12]	[-0.38, -0.24]
Number of Product Names	-0.02	-0.01	0.01	0.02	-0.01	0.04
	[-0.06, 0.02]	[-0.05, 0.03]	[-0.04, 0.06]	[-0.05, 0.09]	[-0.15, 0.15]	[-0.02, 0.11]
Average Price per Dose	-0.07*	0.07*	-0.04	-0.04	-0.10	-0.15*
	[-0.12, -0.01]	[0.02, 0.12]	[-0.12, 0.04]	[-0.09, 0.02]	[-0.18, -0.00]	[-0.22, -0.08]
Number of Doses	0.00	0.07*	0.01	0.04	0.04	-0.01
	[-0.04, 0.04]	[0.03, 0.12]	[-0.04, 0.07]	[0.00, 0.07]	[-0.00, 0.09]	[-0.08, 0.07]
Package-level Price per Dose	-0.09*	0.05	-0.06	-0.11*	-0.11*	-0.17*
	[-0.13, -0.05]	[-0.01, 0.12]	[-0.13, 0.02]	[-0.16, -0.06]	[-0.20, -0.01]	[-0.24, -0.10]
Panel B: Weighted Estimations						
Average Expenditure per Dose	-0.04	0.00	0.03	-0.30*	-0.22*	-0.34*
	[-0.08, 0.01]	[-0.08, 0.10]	[-0.16, 0.27]	[-0.40, -0.18]	[-0.30, -0.12]	[-0.46, -0.20]
Number of Product Names	-0.02	-0.05	-0.00	0.11	-0.03	0.09
	[-0.07, 0.03]	[-0.13, 0.04]	[-0.06, 0.06]	[-0.05, 0.29]	[-0.21, 0.16]	[-0.02, 0.20]
Average Price per Dose	-0.06*	0.17	0.05	-0.17*	-0.05	-0.08
	[-0.11, -0.01]	[-0.00, 0.38]	[-0.12, 0.24]	[-0.25, -0.08]	[-0.18, 0.13]	[-0.36, 0.34]
Number of Doses	-0.04	0.03	-0.07	0.07*	0.02	-0.07
	[-0.12, 0.04]	[-0.05, 0.10]	[-0.16, 0.03]	[0.03, 0.11]	[-0.04, 0.09]	[-0.21, 0.10]
Package-level Price per Dose	-0.08*	-0.03	0.04	-0.20*	-0.07	-0.19*
	[-0.13, -0.03]	[-0.24, 0.13]	[-0.22, 0.38]	[-0.27, -0.11]	[-0.21, 0.16]	[-0.29, -0.08]

Notes: Two-way fixed effects (Denmark 2000 and 2005, Norway 2005) and Callaway and Sant'Anna (2020) (Finland 2003 and 2009, Sweden 2009). Outcome data source: DLI-MI (2007–2013), Farmastat (2004–2013), Fimea (2007–2012), IQVIA MIDAS Quarterly Sales and IQVIA MIDAS (2007–2013). Confidence intervals calculated at the 95% confidence level; * = statistically significant at the 95% level. 10000 replications for ATC-5 wild bootstrapped standard errors.

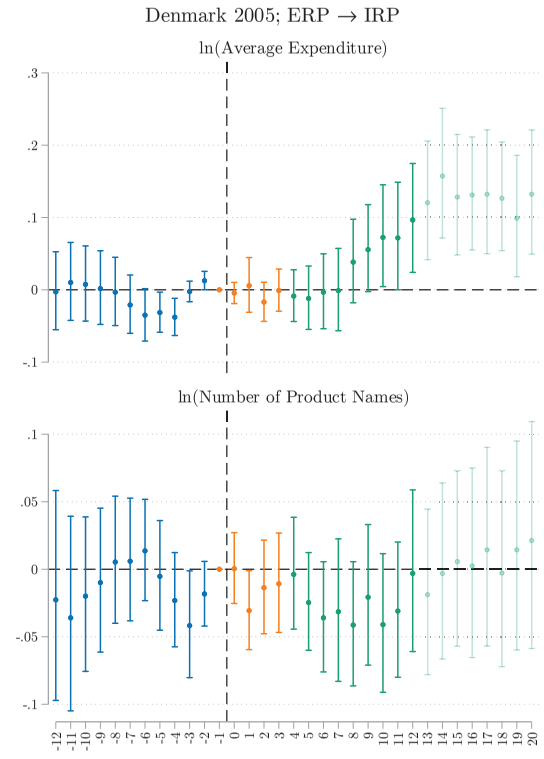
The results of Solon, Haider, and Wooldridge (2015) notwithstanding, we estimate weighted versions to analyze whether our results are driven by small markets. Markets are weighted by their share of the treatment country pharmacy sales of prescription pharmaceuticals. We calculate constant weights from the pre-period, because otherwise the studied reform would also influence the weights we use. We use sales from periods -12 to -6 to construct the weights.

We have compiled the weighted results into Table B.8 where Panel A repeats for comparison the main results presented in Table 6 and panel B provides the weighted ATT results. Starting from our main outcome variables, we find that the results on expenditure are starker once we weigh markets with their size. The three reforms with the largest impacts—the Finnish 2009 GS → IRP, the Norwegian 2005 GS → SP and the Swedish 2009 IRP → Auction-IRP reforms—are estimated to have the same (the Norwegian and the and Swedish reforms) or a clearly larger (the Finnish reform) decreasing impact on expenditure. The results on availability do not change much.

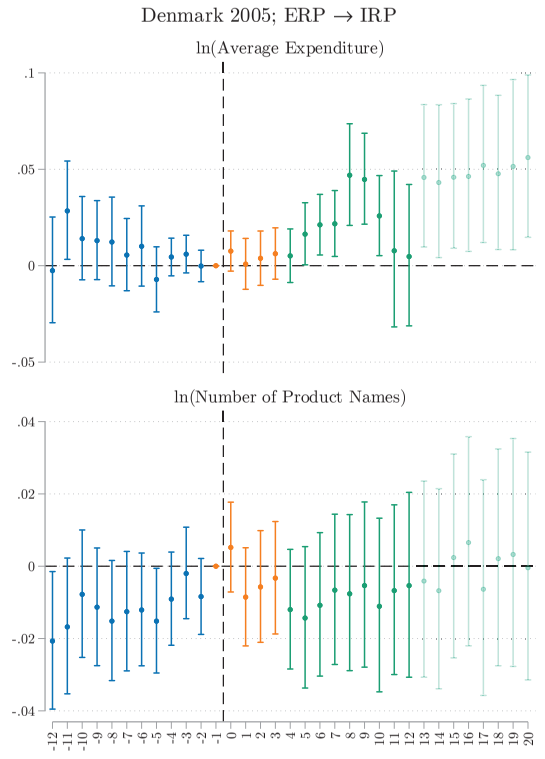
Turning to the secondary outcomes, we find that the Finnish 2009 GS → IRP reform would also have had a significant decreasing impact on the average price per dose. The results on quantity and package-level price are quite similar to those reported in the main text.

B.9 The Danish 2005 ERP→IRP and the Norwegian 2005 IRP→ SP Reforms: Extended Sample Period

In the main text, we showed results for the Danish ERP → IRP and Norwegian IRP → SP 2005 reforms with a short post-reform period. The reason for this choice was the price cut implemented in the control country (Finland) in January 2006. This shock in the control country cannot be "controlled away" in our framework, and the shock directly influences our results. We show event study results for our main outcome variables average expenditure and availability using a longer post-reform time window in Figures 13a and 14a. On the left, we show results for our main markets of interest, i.e., those with generic competition; on the right, we show results for monopoly markets (Denmark) or to markets that are substitutes to regulated markets, but are not directly regulated by the studied consumer choice reform (Norway). The solid-green event study estimates in Figures 13a and 14a represent the results already shown in the main text, and the light-green estimates are the time periods added to the study period. Results for the main outcomes reported in left panels of Figures 13a and 14a are not much affected by the data period extension. The most notable changes in the event study coefficient sizes occur for Danish ERP → IRP 2005 reform monopoly results in Figure 13a. Price cut in the control country mechanically increases the event study estimate size in Figure 13a top panel and the point estimates match closely the price cut size. For Norwegian IRP → SP 2005 reform the data extension had no impact on the spillover results presented in right panel of Figure 14a. The reason for this finding is that these markets are the markets where the Finnish price cut had the largest effect on the wholesale price. The price cut was imposed on the price caps and in competitive markets a large share of products is priced under the price cap and a 5% reduction in the cap does not have a large impact on pricing. In monopoly markets or markets included in our spillover analyses, the price cap cut can have a full 5% decrease in wholesale prices because products in these markets do not face competition and are priced to the cap.

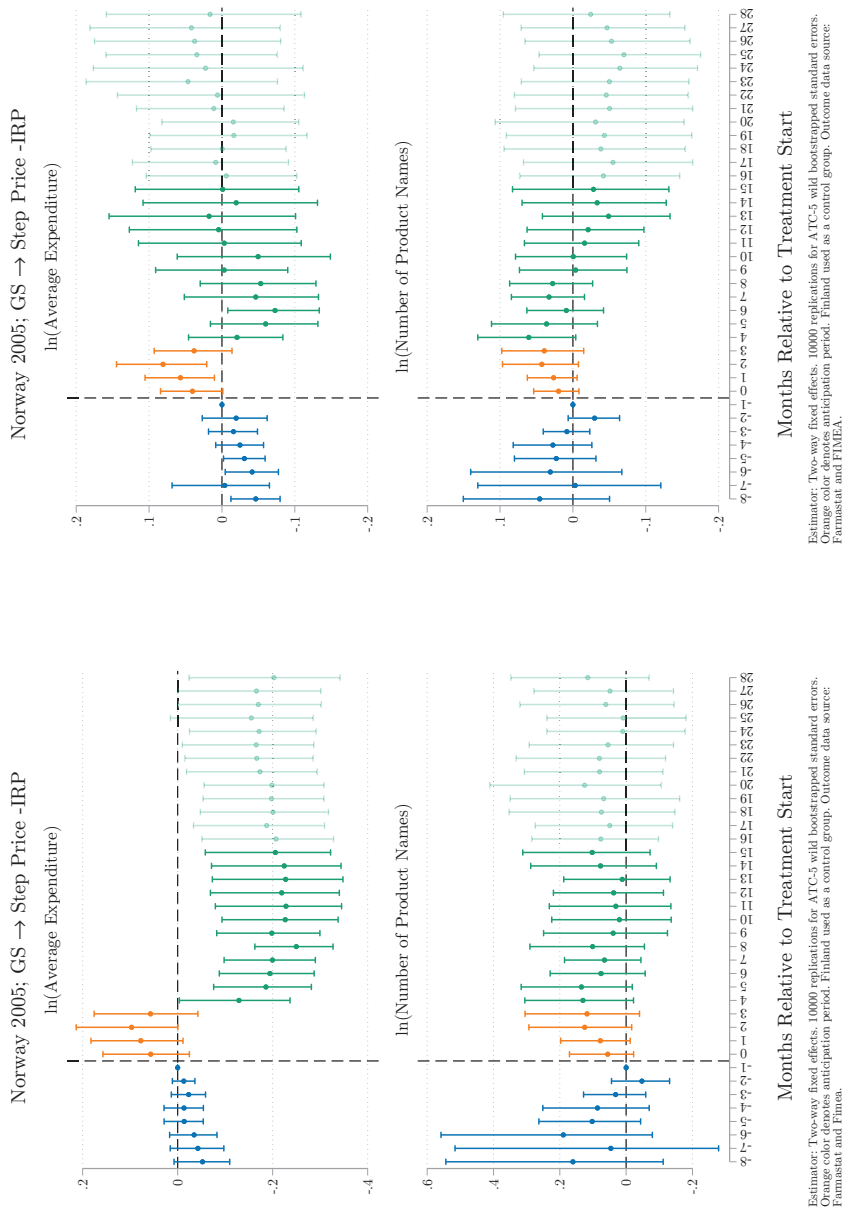


(a) Denmark 2005 – Longer



(b) Denmark 2005 Monopoly – Longer

Figure 13: The Danish 2005 IRP → ERP Results with Extended Follow-up Period.



(a) Norway 2005 – Longer

(b) Norway 2005 Spillover – Longer

Figure 14: The Norwegian 2005 IRP → SP Results with Extended Follow-up Period.

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Essay II

Jaakko Markkanen. Passthrough of Retail Price Regulation in the Market for Pharmaceuticals. *Unpublished manuscript*.

Passthrough of Retail Price Regulation in the Market for Pharmaceuticals *

Jaakko Markkanen

Abstract

I study the transmission of pharmacy mark-ups to retail prices and the policy between retail markups and Value Added Tax (VAT) rates in Finland. My reduced form evidence demonstrates that pharmaceutical manufacturers respond to a decrease in the regulated pharmacy mark-ups by increasing their wholesale prices. I estimate a structural model of pharmaceutical supply and demand using data from the Finnish statin market. I show that only half of the decrease in the pharmacy-markup was transferred to retail prices. I also demonstrate that the government can address the increase in manufacturer revenues by increasing the VAT rate for pharmaceuticals.

Keywords: *pharmaceuticals, passthrough, price regulation*
JEL-Classification: *I11, H51, L51, C23*

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1 Introduction

In Europe, many governments regulate the wholesale and retail prices of drugs. Wholesale price regulation is designed to keep manufacturer prices low, while retail price regulation exists to guarantee uniform consumer prices. This has led to a situation where governments set retail markups for privately owned pharmacies, a practice that is in place in several countries such as Finland, Sweden, Spain, Belgium, and Germany.[1] These markups are high, ranging from 10 to 45% in the case of Finland. From the point of view of a drug manufacturer, government-imposed retail markups are no different from a Value Added Tax (VAT). This expands the classical question of tax incidence to the regulation of markups in the pharmaceutical retail sector. Unlike VAT, the markups fall into the hands of the private sector. This means that while the government controls the markup rates, the additional revenue generated from these markups benefits private pharmacy owners instead of contributing to public funds.

I study the transmission of pharmacy markups to retail prices and the policy between retail markups and VAT rates in Finland. Accurate estimates of the passthrough of taxes or regulation to consumer prices are a crucial aspect of policy evaluation and design. Despite this, policymakers often do not explicitly consider passthrough, or they operate under the assumption of complete passthrough. For example, the last two government proposals on markup regulation in Finland do not discuss or mention the effects of pharmacy markup on wholesale prices or vertical market structure.[2] Moreover, the common practice of VAT subsidies for pharmaceuticals in EU countries implies that policymakers assume that these subsidies benefit consumers directly, rather than increasing the profits of pharmaceutical manufacturers.

I use two methods to study passthrough. I start with a reduced-form model where I estimate the passthrough of a decrease in pharmacy markups to retail prices, utilizing the fact that, due to regulation, not all producers were able to increase their wholesale prices to offset the decrease in pharmacy markups. The reform in question occurred in Finland in 2014. The results suggest that the

1. See Table 2 for an overview of the regulation in European Union (EU) countries.
2. See HE 245/2022 vp and HE 170/2013 for the government proposals (in Finnish).

transfer of markup cuts to retail prices was on average only 28%—implying that pharmaceutical manufacturers were able to capture most of the decrease in retail markups by increasing their own wholesale prices. However, due to threats to internal validity, my reduced-form results are intended only as illustrative evidence to motivate the validity of the research question: There exists a passthrough of retail price regulation to manufacturer prices.

Due to the use of within-country data, the Difference in Differences (DID) identification strategy behind those estimates is based on a strong and perhaps unrealistic Stable Unit Treatment Value Assumption (SUTVA), which states that the potential outcome of every unit does not depend on the treatment status of other units (Imbens and Rubin 2015, p. 10). For example, SUTVA requires that the price of a given product is not influenced by the prices of competitors. This assumption of no equilibrium effects contradicts both theoretical models of competition and empirical evidence (Minton and Mulligan 2024). Because I want to estimate product-level markup and tax incidence, I cannot rely on the standard procedure of aggregating product-level data to the market level. Moreover, in recent empirical reseach, Alves, Burton and Fleitas (2024) combine a structural model of housing demand and supply with a DID application to study the SUTVA violations. In their application on the housing market in Uruguay, the SUTVA violations account for a quarter of the total estimated effect.

The existing literature has cast doubt on the feasibility of reduced-form estimates to yield unbiased estimates of passthrough. MacKay, Miller, Remer and Sheu (2014) show that the standard approach of regressing prices on costs yield unbiased estimates of passthrough only if passthrough is constant. In practice, this means that most reduced-form estimations indirectly restrict the underlying demand system to linear, log-linear, or constant-markup systems. Furthermore, MacKay, Miller, Remer and Sheu (2014) decompose the bias into two parts: regression misspecification and partial information bias. The former arises when the cost distributions are skewed or when the magnitude of passthrough is a function of costs. The partial information bias results from observing the marginal costs only partially when the magnitude of passthrough is a function of costs and the unobserved and observed cost shocks are not independent. Both of these biases are problematic assumptions in my application. First, if firms set their prices following

the Lerner rule, the passthrough rate is directly related to their marginal costs unless the price elasticity of demand is constant. Second, in my application, I do not observe most of the determinants of marginal costs, such as labor, material, or transportation costs.

To avoid the pitfalls of reduced-form techniques, I also estimate a structural model of supply and demand using data from the Finnish cholesterol drug market. The demand model is a random utility discrete choice model, and the supply model is based on Bertrand-Nash competition with retail price regulation. My estimates yield an average passthrough rate of approximately 58%.[3] My structural estimates imply that manufacturers benefited significantly from the policy change, increasing their profits by almost than five million euros during the years 2014–2017 in the statin market alone. However, consumers and the public sector saved more than five million euros combined in pharmaceutical expenditure. Since pharmacies lost a total of total million euros, the decrease in pharmacy markups was a transfer of rents from downstream pharmacies to consumers and to upstream drug manufacturers.

My results are especially important for small open economies without a significant domestic pharmaceutical industry, such as Finland. In such a country, the regulator should pay attention to the vertical market structure between manufacturers and the retail sector, because the retail price regulation is passed through to manufacturer prices. Cost control policies in the retail sector, such as markup regulation, can increase manufacturer prices. In essence, this increases manufacturer profits and foreign imports, as the small size of the Finnish pharmaceutical manufacturing sector means that most pharmaceuticals are sourced from abroad. I show that the policy maker can take this into account by preferring VAT as a policy tool against retail price regulation, especially if the government reimburses most of the pharmaceutical costs. To this extent, VAT can serve as a mechanism to offset the effects of market power and imperfect competition by reducing manufacturers' prices, thereby decreasing the aggregate cost of pharmaceuticals for society. In theory, its effects on individual consumers—based on the second fundamental theorem of welfare economics—are a distributional question that the government can take into consideration either within the reimbursement system or by transfers.

3. Because my reduced-form estimation sample consists of different products and different markets, these two estimates cannot be used to evaluate the SUTVA concerns of the DID approach.

This paper is related to three different strands of literature. First, it is related to the literature on passthrough and tax incidence, with an application to pharmaceutical markets and regulation.[4] A key result in the theoretical literature, demonstrated by Weyl and Fabinger (2013), show that under imperfect competition, the level of passthrough depends not only on the demand elasticities—like in models of perfect competition—but also on the curvature of the demand. In the econometric literature, Miravete, Seim and Thurk (2023) study the properties or demand curvature in common discrete choice models. They show that traditional multinomial logit demand models truncate the demand curvature and the respective passthrough rates to below one, ruling out passthrough rates higher than 100%. Furthermore, Miravete, Seim and Thurk (2023) show that heterogeneity in the price coefficient plays an important role in the degree of demand curvature that the demand system can support.

Building on these general results, I contribute to the applied literature by demonstrating how pharmaceutical price controls can function as a form of taxation through regulation. However, compared to price regulation, the VAT can address some of the effects of imperfect competition that price regulation cannot. Although my contribution focuses on a specific context and represents an edge case, it offers a practical application of the broader principles established in the literature. I achieve this by employing a structural model with a flexible demand system, adhering to existing best practices in demand estimation.

Most importantly, my work in this paper borrows the vertical structure of the supply model from Miravete, Seim and Thurk (2018, 2020) who study the taxation of spirits in Pennsylvania, a state that monopolizes the retail sales of alcoholic beverages. In Miravete, Seim and Thurk (2018), the authors estimate a random coefficient nested logit demand model with demographic interactions. Combined with a vertical supply model, the authors use these estimates to measure manufacturers' pricing responses to taxes. They find that distillers respond to decreases in the tax rate by increasing wholesale prices. Miravete, Seim and Thurk (2020) investigate the redistribution effects of uniform taxation of spirits

4. Notable examples from this literature include Wang (2015) (soda taxes) Duggan, Starc and Vabson (2016) (health insurance) Hong and Li (2017) (grocery retail) Conlon and Rao (2020) (excise taxes) Benzarti, Carloni, Harju and Kosonen (2020) (VAT) Hollenbeck and Uetake (2021) (marijuana taxes).

in Pennsylvania by comparing it to revenue-maximizing product-level markups and consumer welfare-maximizing "Ramsey" tax policies. They find that uniform taxation of spirits decreases tax revenue and consumer welfare compared to either alternative.

Second, I contribute to the reduced-form literature studying the effects of regulation in pharmaceutical markets. Most existing research has focused on studying the effects of consumer choice policies and regulation on pharmaceutical prices and expenditure (Pavcnik 2002; Brekke, Grasdal and Holmås 2009; Brekke, Holmas and Straume 2011; Kortelainen, Markkanen, Toivanen and Siikanen 2023). However, Danzon and Chao (2000) presents some descriptive evidence that the regulation of pharmacy markups undermines competition and the savings potential of generic competition. The results from both my reduced-form and structural models verify that the regulation of pharmacy markups also affects pharmaceutical manufacturers and competition. My findings demonstrate that pharmaceutical manufacturers respond to regulations targeting downstream retailers.

This paper is also related to the structural estimation of pharmaceutical demand (Duso, Herr and Suppliet 2014; Kaiser, Mendez, Rønde and Ullrich 2014; Dubois and Sæthre 2020; Dubois, Gandhi and Vasserman 2022; Atal, Cuesta and Sæthre 2022; Janssen 2023). I contribute to the literature by modeling the vertical market structure under strict retail price controls established by the government. Dubois and Sæthre (2020) study the effects of parallel trade on negotiations between pharmaceutical manufacturers and pharmacy chains in Norway. In my application, there is no bargaining between the upstream and downstream firms because of government regulations; the manufacturer is tied to uniform prices throughout the country. This significantly simplifies the estimation of tax passthrough.

The remainder of this paper is structured as follows. I summarize the regulatory environment of the Finnish pharmaceutical market in Section 2. Section 3 gives an overview of my data. I present the descriptive reduced-form evidence in Section 4. Section 5 introduces my structural model for the statin market, and Section 6. I offer my conclusions in Section 7.

Table 1: Retail prices for RX drugs in Finland

Wholesale price (WP)	Retail price (2003)	Retail price (2014)	Retail price (2023)
0–9,25	1,5 × WP + 0,50 €	1,45 × WP	1,42 × WP
9,26–46,25	1,4 × WP + 1,43 €	1,35 × WP + 0,92 €	1,35 × WP + 0,52 €
46,26–100,91	1,3 × WP + 6,05 €	1,25 × WP + 5,54 €	1,24 × WP + 4,92 €
100,92–420,47	1,2 × WP + 16,15 €	1,15 × WP + 15,63 €	1,15 × WP + 13,92 €
over 420,47	1,125 × WP + 47,68 €	1,1 × WP + 36,65 €	1,10 × WP + 33,92 €
over 1 500			1 × WP + 183,92 €

Notes: Retail prices are determined by the government for RX and OTC pharmaceuticals. This table presents the pharmacist's pricing formula for prescription products. The retail prices here do not include the VAT.

2 Institutional Background

2.1 The Finnish market for pharmaceuticals

I study the Finnish pharmaceutical market, which can be characterized by a vertical supply chain where upstream manufacturers set their wholesale prices at the national level (uniform pricing) and downstream retailers (pharmacies or pharmacists) distribute the drugs to consumers. Pharmacies do not set their own prices, but instead the government regulates the retail prices of all pharmaceuticals as a linear function of wholesale prices. The government also collects 10% VAT on the retail price.[5] Table 1 presents pharmacy markups between 2003–2013 and 2014–2023 for prescription (RX) drugs. Markups were cut in 2014 to induce savings in pharmaceutical expenditure, more than two-thirds of which are covered by the public sector. The markups of over-the-counter (OTC) drugs are also regulated by the government and were in the 2003 RX regime (Table 1, Column 2) until 2022 when the markup rule changed from a binding formula to the maximum markup, thus allowing price competition for OTC drugs.

Finland has a public reimbursement system for pharmaceuticals. The reimbursement rate varies from 40% to 100%, depending on the severity of the disease for which the drug is used. There also exists an annual expenditure cap, after which the consumer is fully reimbursed expect for a small fixed co-payment per prescription. Wholesale prices of publicly reimbursed pharmaceuticals are subject to price caps that are negotiated between the government and pharmaceutical

5. The tax rate for pharmaceuticals was 9% before 2012, see Value Added Tax Act 1202/2011.

manufacturers.[6] These price caps are the main regulatory tool to control the costs of publicly reimbursed monopoly drugs. However, it should be noted that these price caps are only part of the reimbursement system. Any company that has market authorization from Finnish Medicines Agency (Fimea) or European Medicines Agency (EMA), can sell their product at any price they like if it is not included in the reimbursement system.

At the time of loss of exclusivity and the start of generic competition, the former price caps are no longer renegotiated, but they remain in place. However, these products are then subject to reference pricing, under which the government caps the level of reimbursement to a reference price, which is based on the lowest price within a set of substitutable products. The substitution groups are determined by Fimea. These reference prices are set and updated quarterly.

In my reduced-form estimations, I take advantage of the fact that some products were subject to binding price caps at the time of the markup reform 2014. For these products, pharmaceutical manufacturers were unable to increase their wholesale prices to benefit from the reform. On the other hand, for all those products that had no price caps or whose price caps were not binding, firms were able to partly or even fully capture the change in retail prices induced by the reform. In theory, companies could set their new wholesale price at the exact level where retail prices remained constant. Thus, the existence of these two groups of products—separated by the price cap regulation—creates a quasi-experimental setting to study the passthrough of the markup regulation to wholesale prices.

2.2 Pharmacy markup regulation in the European Union

In this subsection, I briefly discuss the regulatory environment in the EU single market with regard to pharmacy markup regulation and VAT rates. This discussion is motivated by the fact that many EU countries mandate pharmacy markups and offer subsidized VAT rates for pharmaceuticals. The overview presented in this subsection highlights the broader relevance of my results beyond Finland. Table 2 provides an overview of pharmacy markup regulation in EU countries, listed in

6. Notice that due to regulation wholesale prices are actual transaction prices and not estimates, so there should be no concerns over measurement errors.

Table 2: Pharmacy Markup Regulations in the EU

Country	PRP formula	PRP cap	Market value	VAT (RX)	VAT (OTC)	Standard VAT
Germany	Yes	Yes	42 962	19%	19%	19%
France	No	Yes	29 552	2.1%	10%	20%
Italy	No	Yes	23 446	10%	10%	22%
Spain	Yes	Yes	17 604	4%	4%	21%
Poland	Yes	Yes	7 239	8%	8%	23%
Belgium	Yes	Yes	6 303	6%	6%	21%
Netherlands	No	Yes	6 185	9%	9%	21%
Greece	Yes	Yes	5 381	6%	6–13%	24%
Austria	No	Yes	4 827	10%	10%	20%
Sweden	Yes	Yes	4 570	0%	25%	25%
Romania	No	Yes	4 500	9%	19%	19%
Portugal	No	Yes	3 524	6%	6%	19%
Czech Republic	No	Yes	3 389	10%	10%	21%
Denmark	Yes	Yes	3 243	25%	25%	25%
Finland	Yes	Yes	2 762	10%	10%	24%
Hungary	Yes	Yes	2 558	5%	5%	27%
Ireland	No	No	2 354	0–23%	0–23%	23%
Slovakia	Yes	Yes	1 461	10%	20%	20%
Bulgaria	No	Yes	1 414	20%	20%	20%
Croatia	No	Yes	1 036	5%	5%	25%
Lithuania	No	Yes	866	5%	21%	21%
Slovenia	No	Yes	743	9.5%	9.5%	22%
Estonia	No	Yes	359	9%	9%	20%
Latvia	No	Yes	275	12%	12%	21%
Malta	No	No	196	0%	0%	18%
Luxembourg	Yes	Yes	184	3%	3%	17%
Cyprus	No	No	177	5%	5%	19%
% ´Yes´	41%	89%	-	-	-	- %
Total	11	24	177110	-	-	- %

Notes: The first two columns indicate whether a country uses a formula to determine the retail price in pharmacies and whether there is a cap on pharmacy margins or prices. The third column displays the pharmaceutical market value in millions of euros for the year 2020. The last three columns show VAT rates for RX and OTC pharmaceuticals and the standard VAT rate. In Ireland, the VAT is 0% for oral medications and 23% for others.

descending order of pharmaceutical market value, with Germany being the largest market.

Column 2 shows which EU countries use a pricing formula to determine Pharmacy Retail Prices (PRPs), as is the case in Finland, and Column 3 shows which countries have a price cap on PRPs. The column 'PRP formula' shows if government regulations directly set the retail markups for pharmaceuticals, resulting in uniform prices across all pharmacies. Most countries that do not directly regulate pharmacy prices regulate them with price caps; Ireland, Malta, and Cyprus are the exceptions that do not directly regulate PRPs. For example, Ireland negotiates pharmacy markups for prescription drugs with the pharmaceutical industry.

Columns 4 and 5 present the VAT rates on prescription and OTC drugs, respectively. Column 6 shows the standard VAT rate in each country. The table shows that only Germany, Denmark and Bulgaria use the highest possible VAT bracket for RX drugs. Since catastrophic health spending—defined as a percentage of income and using a threshold of 40% of household capacity to pay for health care—is more likely among lower income households (OECD and European Union 2022, p. 177), it is likely that countries use lower VAT brackets as a mean of subsidizing poorer households. The reduced VAT brackets have long been under scrutiny, and a more uniform tax rate would likely generate more tax revenue and improve consumer welfare because the reduced VAT brackets distort relative prices between different goods and services (Mirrlees and Adam 2010). My results in Section 6 highlight an additional argument for the abolition of the reduced tax brackets (at least for pharmaceuticals) by showing that, in practice, the reduced tax rates can operate as a tax subsidy for manufacturers.

3 Data

I use data from Fimea and the Association of Finnish Pharmacists (AFP). The first data set contains monthly package-level wholesale data on the sales value and volume of each pharmaceutical package sold on the Finnish pharmaceutical market.[7] These data measure the purchases pharmacies make from wholesalers. I

7. Due to the design of the regulatory environment, my data does not suffer from the measurement error issues common in pharmaceutical data from the United States (Ippolito and Levy

Table 3: Reduced Form Sample Descriptive Statistics

	Treatment	Control
Mean Prices	63.29	140.96
	(1.22)	(20.18)
Mean Sales	18983.01	28828.84
	(464.97)	(3804.28)
# molecules	344	70
# firms	176	60
# packages	930	221
# observations	19666	4602

Notes: This table presents the descriptive statistics of the reduced form estimation sample. Outcome data source: Fimea (2013–2014). Prices and sales in nominal euros.

complement this data set with price regulation information from the AFP. With price regulation information, I identify which products are subject to binding price caps.

For my reduced-form analysis, I restrict my estimation sample in several different steps. First, I limit my estimation window to years 2013–2014 or 24 months. Second, I include only products whose price caps remained constant throughout the period to isolate the effect of the markup reform from possible price cap renegotiations occurring at the same time. Finally, I restrict my sample so that the control group and the treatment group do not contain products within the same Anatomical Therapeutic Chemical classification system (ATC) group 5 (the same molecule or active incredient). This addresses the risk of general equilibrium effects, as all substitution between prescription drugs can legally occur at the molecule-strength-package size level. Thus, the substitution of drugs with different molecules could occur only by the prescribing physician's decision. This restriction also excludes a potential situation in which the products in the control group would be strategic substitutes for the products in the treatment group.

Table 3 provides the relevant descriptive statistics for this sample by treatment status. Products included in the treatment group (products with nonbinding price caps) are, on average, more expensive at the package level than products in the control group. However, the monthly total sales are on average larger for products

2022).

in the control group. The treatment group is significantly larger in size than the control group, with 344 molecules compared to the 70 molecules in the control group and more than four times the number of packages and observations. My estimation sample consists of significantly more active incredients than the existing reduced-form literature on pharmaceuticals, with the notable exceptions of Kortelainen, Markkanen, Toivanen and Siikanen (2023) and Granlund and Bergman (2018) whose samples consist of several hundreds of active ingredients. Other existing studies have typically studied only a few substances at a time.[8]

In my structural estimations, I complement my Finnish data sources with pharmaceutical price data from Sweden, Denmark, and Norway. I use these data to construct Hausman-like instruments for my demand model. I describe this process in more detail in Section 5.4. The data sources are listed in Appendix Section A.1. I also limit my analysis to statins (ATC4 level C10AA consisting of six molecules), and aggregate the sales data to the quarterly level. I focus on the statins market for several reasons. First, modeling all drug classes would be a burdensome exercise both conceptually and computationally.[9] Some drug markets serve chronic diseases, while others are used for the treatment of acute diseases. With or without public reimbursement, some markets are generic markets, while others are monopoly markets with active patents, complicating the regulatory environment. Therefore, it is unlikely to find a one-size-fits-all model that fits the data well.[10] Second, the statin market has been the subject of interest in previous studies in the literature, such as Kaiser, Mendez, Rønde and Ullrich (2014) and Saxell (2014), which allows me to compare my estimates with the results in the existing literature.

The descriptive statistics of this sample are presented in Table 4. During the data sample, the most expensive drug on average was rosuvastatin, and the most inexpensive drug was lovastatin. Simvastatin had the largest market share at the

8. For a short review, Brekke, Grasdal and Holmås (2009) studied six molecules, Brekke, Holmas and Straume (2011) eight and Brekke, Canta and Straume (2015). The Pavcnik (2002) sample consists of three ATC3 classes.

9. My experiments with other markets has faced computational issues. The regulatory environment and small elasticities make it difficult to extend the model beyond statins.

10. Notable exceptions are (Dubois, Gandhi and Vasserman 2022; Atal, Cuesta and Sæthre 2022). The former studies the American and Canadian hospital drug markets, and the latter studies the Chilean retail market. Both markets lack the common regulatory environment in European countries such as Finland.

Table 4: Statins Market Descriptive Statistics

	C10AA01 Simvastatin	C10AA07 Rosuvastatin	C10AA05 Atorvastatin	C10AA02 Lovastatin	C10AA03 Pravastatin	C10AA04 Fluvastatin	Total
Retail Price	27.73	58.06	35.51	23.40	28.09	24.73	36.69
	(27.51)	(44.19)	(20.96)	(13.63)	(19.28)	(14.48)	(32.13)
Package Size	73.54	63.08	68.35	77.41	73.60	69.72	69.60
	(33.82)	(35.18)	(34.60)	(32.34)	(33.88)	(34.56)	(34.61)
Unique Firms	8.84	6.26	5.76	2.92	3.55	3.07	6.43
	(1.83)	(1.35)	(0.48)	(1.18)	(0.72)	(0.66)	(2.35)
Unique Products	50.82	40.47	39.25	8.15	11.12	10.07	38.14
	(11.86)	(10.49)	(3.32)	(3.86)	(2.51)	(2.03)	(16.40)
Sales (PRP)	19.66	13.94	21.75	0.64	1.41	2.42	60.72
	(8.98)	(2.24)	(7.71)	(0.15)	(0.28)	(0.54)	(17.76)
Sales (PPP)	12.08	9.19	14.01	0.40	0.89	1.54	38.73
	(6.10)	(1.57)	(5.23)	(0.09)	(0.20)	(0.33)	(12.23)
Market Share	50.83	14.07	31.91	0.82	2.44	3.01	100.00
	(8.70)	(3.09)	(6.66)	(0.28)	(0.25)	(0.56)	(0.00)

Notes: This table presents the descriptive statistics for the variables used in the estimation. Data sample 2010–2017. Mean values are presented in the first row, and standard deviations in parentheses. Sales in annual pharmacy retail prices (PRP) and pharmacy purchase prices (PPP), both in millions of nominal euros.

molecule level, with an average annual market share of more than 50%. Simvastatin also had, on average, the most manufacturers and packages on the market, while lovastatin had the fewest. The average annual sales of all statins during the sample period was approximately 60 million euros at retail prices (including the VAT) or 38 million euros at wholesale prices.

4 Reduced Form Evidence

The empirical design in my reduced-form analysis is based on DID. I take advantage of the fact that due to the binding wholesale price cap regulation, not all firms were able to respond to the change in the retail markups by increasing their prices. By construction, this assumes that the firms' best response is to increase their prices when the markup formulas in Table 1 were changed. This assumption is illustrated by equation (9) of my supply model in Section 5. The equation demonstrates that the partial derivatives for wholesale prices are positive with respect to the pharmacy markups and the VAT rate. My treatment group consists of products that did not have binding price caps at the time of policy change, and my control group consists of products with products that had binding price caps.

Equation (1) presents my event study model to estimate the passthrough of the decrease in pharmacy markups:

$$y_{it} = \alpha_i + \lambda_t + \sum_{\tau \neq -1} \beta_\tau \text{Reform}_{i\tau} + \epsilon_{it} \tag{1}$$

where y_{it} represents the outcome of interest, which is the percentage change in retail prices relative to the base period $t^* = -1$, the month before the regulatory change, for the product i in period t, i.e., $(PRP_{j,t} - PRP_{j,t^*})/PRP_{j,t^*}$. This outcome variable is related to the measurement of tax passthrough in the public finance literature, for example Kosonen (2015) and Harju, Kosonen and Skans (2018). The term α_i denotes the package-level fixed effects and λ_t denotes the period (year-month) fixed effects. The $\text{Reform}_{i\tau}$ variables indicate the time-to-treatment, set to 1 for treated products at time t when τ periods have elapsed since the start of treatment. The coefficients β_τ capture the average treatment effects from time τ to the period just before treatment. I also estimate the average treatment

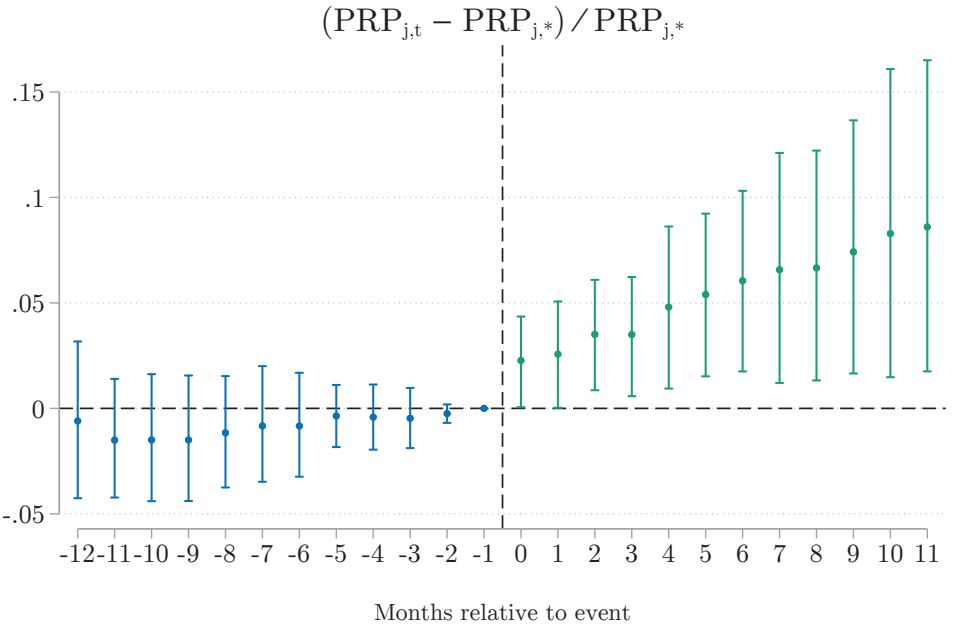
effect using a canonical 2×2 DID setup where I change equation (1) by replacing $\sum_{\tau>-1} \beta_\tau \text{Reform}_{i\tau}$ with $\beta_{ATT}\text{Reform}_i$. In this case, β_{ATT} can be interpreted as the average impact of the reform on the treated units.

Although my reduced-form evidence is intended only as an illustrative example, the parameters $\hat{\beta}_\tau$ and $\hat{\beta}_{ATT}$ can be interpreted as causal under specific identifying assumptions. These assumptions are the usual: I require the parallel trends assumption and SUTVA. The former assumes that the prices in the treatment group would have, on average and across all periods, evolved similarly to the prices in the control group in the absence of treatment. The latter assumes that the treatment assignment of any product does not affect the potential outcome of any other product.

The event study results are presented in Figure 1. These results clearly indicate that at the beginning of the new markup regulation ($t = 0$), the retail prices of the products in the treatment group started to increase relative to the control group. At the start of the new regime, the dynamic treatment effects imply that retail prices in the treatment group increase by approximately 4 percentage points relative to the control group. After 12 months, the effect is close to 10 percentage points. All dynamic effects are statistically significant at the 95% level. The ATT results are presented in Figure 2. The average effect of treatment was 0.069 and statistically significant, which corresponds to an increase of 6.9 percentage points in the retail prices of products in the treatment group.

Note that in this particular case, the products in the control group were also subject to a change in pharmacy markups. However, because these products were subject to binding price caps, pharmaceutical companies were unable to increase their prices, and mechanically the change in retail markups was fully transferred to their retail prices. Thus, the counterfactuals (the potential outcomes) in the reduced-form exercise are slightly different from those in the DID literature. The control group gives a counterfactual of complete passthrough to estimate the degree of partial passthrough for the products in the treatment group. Thus, to compute the actual passtrough of the markups, I need to compare the aggregate change of prices in the treatment group with the price changes in the control group. Figure 2 shows the estimate of the linear combination of $\hat{\gamma}_{Post} + \hat{\beta}_{ATT} = -0.022$. However, this estimate is not statistically significantly different from zero. Since

Figure 1: Event Study Estimates

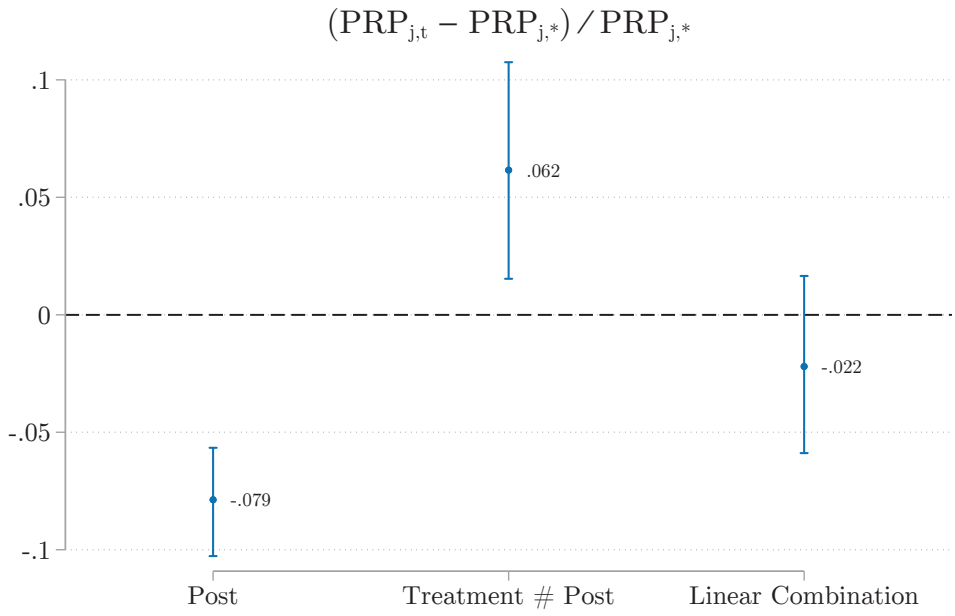


Notes: This figure present the event study estimates for equation (1). Outcome variable: Change in retail prices relative to December 2013. Estimator: Two-Way Fixed Effects (TWFE) with bootstrapped standard errors clustered at the ATC3 level (10000 replications).

the term $\hat{\gamma}_{Post}$ is related to the case of full passthrough, I can calculate the partial passthrough rate by dividing my linear combination estimate by the term $\hat{\gamma}_{Post}$. This yields me the final estimate of 28% for the passthrough of the change in pharmacy markups. Conceptually, measuring passthrough by the comparison of consumer prices relative to full passthrough again follows the previous literature on the estimation of tax passtrough with reduced-form methods (Kosonen 2015; Harju, Kosonen and Skans 2018).

These results should only be interpreted as descriptive due to possible SUTVA violations. Although I restrict my sample so that there is no direct competition between the treatment and control groups, SUTVA also requires that the treatment

Figure 2: ATT Estimates



Notes: This figure present the ATT estimates for equation (1). Outcome variable: Change in retail prices relative to December 2013. Estimator: TWFE with bootstrapped standard errors clustered at the ATC3 level (10000 replications). The implied passthrough can be calculated from the ATT result by dividing the linear combination with the base level. This yields $(\frac{-0.022}{-0.079}) \times 100\% \approx 28\%$.

statuses of the products within the treatment (or control group) should not affect the potential outcomes of other products in the same group. However, since they can be direct substitutes within the treatment or control group, this assumption is not satisfied (Minton and Mulligan 2024). Furthermore, it should be obvious that products that I discard from the sample could also affect these estimates.[11] The direction of the bias from SUTVA violations depends on the nature of competition between and within the control and treatment groups. However, if more products

11. Recall that I also required that the sample is a fully balanced panel. Thus, I cannot guarantee that my sample includes every product with the same molecule.

are strategic substitutes, the estimates are biased upward because the best response to any price change is in the opposite direction. If more products are strategic complements, there is a downward bias, as the best response is to adjust prices in the same direction. Empirically, the direction of the bias will depend on the distribution of substitution patterns between the products.

The above issues highlight how substitution patterns influence pricing dynamics. However, even as descriptive evidence, my results demonstrate that compared to the control group and full passthrough, products that could increase their wholesale prices had smaller decreases in retail prices after pharmacy markups were reduced.

5 A Structural Model of the Statin Market

In this section, I present my structural model for the statin market in Finland. Statins, a class of medications, are primarily used to lower blood cholesterol levels, especially bad LDL cholesterol. They function by inhibiting an enzyme in the liver essential for cholesterol production (Cholesterol Treatment Trialists Collaboration et al. 2005, 2010). Statins are divided into two generations: First-generation statins, such as lovastatin and simvastatin; and second-generation statins, including atorvastatin and rosuvastatin, which are often considered more potent. These medications are typically consumed for long periods, often for a lifetime, due to their role in the management of chronic diseases such as cardiovascular disease and the prevention of heart attacks and strokes. The existing literature on the structural estimation of statin demand includes Dunn (2012), Kaiser, Mendez, Rønde and Ullrich (2014), Dubois and Sæthre (2020) and Janssen (2023). Of these articles, Kaiser, Mendez, Rønde and Ullrich (2014) define their markets—and thus the underlying choice sets—as the whole universe of statins while Dubois and Sæthre (2020) studies the demand for atorvastatin with prescription data so that the demand for other statins enters through the market share of the outside option. Janssen (2023) also uses a narrower definition in which markets are defined at the level of substitution groups. Although the latter might be a realistic representation of consumer choice in pharmacies (since consumers are tied to their prescriptions), the market definition in Janssen (2023) requires that the demand and supply between these substitution groups are unrelated.

I first present my demand model, followed by the supply model and the calculation of marginal costs. I then present estimation of passthrough. I conclude the section by discussing the identification and estimation of the models.

5.1 Demand model

Consumer i obtains indirect utility from a standard unit of dosage in package $j \in J$ in market $t \in T$ following the structure shown in equation (2). Each market t is defined as a quarter of a year, so all statin products sold in a given quarter belong to the same market across active incredients, strengths, package sizes, and dosage forms.[12]

$$u_{ijt} = \sigma_j^D + \tau_t^D + \sum_k \beta^k x_{jt}^k - \alpha_i p_{jt}^r + \xi_{jt} + \epsilon_{ijt} \tag{2}$$

The terms σ_j^D and τ_t^D in equation (2) represent the demand side-fixed effects that include molecule, year, and quarter period dummies. The exogenous product characteristics, x_{jt}, include log package sizes and an indicator for the brand (originator drug) status. ε_{ijt} is a consumer-specific demand shock that follows a Type I Extreme Value distribution, yielding the well-known mixed logit choice probabilities (Berry and Haile 2021).

The endogenous term in equation (2) is the price term, p_{jt}^r which is assumed to be correlated with the unobserved quality or demand schocks ξ_{jt}. This is due to the dependence between profit-maximizing prices and other unobservable factors that also affect demand. For example, firms are likely to increase their prices if there is a positive demand shock. The main endogeneity issue arises from time- and product-specific shocks not controlled by fixed effects. In the statin market, high consumer inertia means that patients tend to stick to their initial prescription, leading older patients to use first-generation statins while newer statins are prescribed to younger or higher-risk patients. These differences in consumer bases, shaped by evolving demographics or regulatory trends such as reimbursement rules, can generate demand shocks that fixed effects cannot fully capture.

Because drugs are sold in different strengths and package sizes, the price term

12. I have aggregated the data to the quarterly level. Prices are calculated by dividing total sales by sold quantities.

cannot be measured at the actual package-level price. Otherwise, the econometrician would impose a greater weight on small packages with less potent drugs in the calculation of market shares. The existing literature has solved this problem by measuring quantities and prices in terms of some standard units (Dubois and Lasio 2018; Dubois and Sæthre 2020), or using expenditure shares rather than quantity market shares. The latter approach was first used by Björnerstedt and Verboven (2016), and has since been used in the structural pharma-literature by Atal, Cuesta and Sæthre (2022). In that specification, prices would enter logarithmically and the market shares, and the size of the potential market is measured in expenditure shares. I choose to follow the former approach, which is closer to the canonical demand models in the literature. I measure the price by the price of the package divided by the number of Defined Daily Dosagess (DDDs) included in a package.[13] Thus, market shares will also be measured in terms of the number of doses sold.

An important part of my demand model is the distributional assumption on the price coefficient α_i. In a standard multinomial logit case, the model would assume that consumers have homogeneous preferences over price. This assumption, however, has stark consequences on the elasticities and rates of passthrough the underlying demand system can support. Miravete, Seim and Thurk (2023) show that a standard multinomial logit model can only produce standard passthrough estimates truncated at 100%. In comparison, allowing heterogeneity in the price term allows for more flexible elasticities and rates of passthrough. In my main approach, I follow Miravete, Seim and Thurk (2023) by assuming that the price coefficient follows a log-normal distribution $\alpha_i \sim \log \mathcal{N}(\alpha, \Sigma_\alpha)$ which imposes downwards-sloping demand for all consumers. For comparison, I also consider a specification where the coefficient follows a normal distribution.

Note that studying drug markets using a discrete choice model of demand is inherently different from studying the demand for breakfast cereals or cars. Under generic substitution, consumers can only freely choose between the exact prescribed products and its direct substitutes. For example, a patient with a prescription for a dose of 10 milligrams of simvastatin can only substitute between exactly

13. DDD is a measure used in health and pharmaceutical studies. It was developed by the World Health Organization (WHO). The DDD is defined as the normal maintenance dose per day for a drug used for its main indication in adults.

those products, not 20 milligrams of simvastatin or any other statin. Therefore, in most cases, consumers are tied to the decision that the prescribing physician makes. As argued by Crawford and Shum (2005) and Dubois and Lasio (2018), drug demand with aggregate data is always a mixture of physician prescriptions, regulation, and patient preferences, not just pure consumer choice. My model does not separate interactions between patients, physicians, and pharmacists during prescription and purchase. For these reasons, I also abstract away from explicitly modeling regulation related to consumer choice—such as reference pricing—in my demand model.

5.2 Supply model

Although my demand model does not include regulation that influences consumer choice, I explicitly model the vertical structure and markup regulation in my supply model. However, the maximum wholesale price regulation makes the estimation of the supply side slightly more difficult than in standard IO applications. I assume that firms compete Bertrand-Nash, that is, firms maximize:

$$\underset{p^w_{jt}}{\text{maximize}} \quad \sum_{j \in J^f} \overbrace{(p^w_{jt} - c_{jt})}^{\text{Wholesale markup}} \times M_t \times s_{jt}(\underbrace{p^r_{jt}(p^w_{jt})}_{\substack{\text{Markup} \\ \text{formula}}}, x, \xi; \theta),$$

$$\text{subject to} \quad p^w_{jt} \leq \bar{p}^w_{jt} \tag{3}$$

with respect to their wholesale prices p^w_{jt}. Because of regulation, firms are subject to price caps $\bar{p}^w_{jt}$ imposed by (or negotiated with) the government. The vertical market structure is well visible in equation (3): markups for pharmaceutical manufacturers consists of the price difference between the wholesale price and the marginal cost c_{jt}, but the market shares s_{jt} are a function of retail prices p^r_{jt} which is a function of wholesale prices. Note that the marginal costs, as well as the prices, are in terms of DDDs. Because some firms are subject to binding price caps, it is not possible to retrieve their marginal costs using standard first-order conditions. The objective

function yields the following first-order conditions:

$$s_{jt}(p^r(p^w), x, \xi; \theta) + \underbrace{\sum_{m \in J^f}}_{\substack{\text{Sum over} \\ \text{products} \\ \text{of firm } f}} (p^w_m - c_m) \times s_{mt}(p^r(p^w), x, \xi; \theta) \times \frac{\delta s_m}{\delta p^w_j} \underbrace{\geq 0}_{\text{Binding price caps}} \tag{4}$$

where the last term captures the changes in quantities (of all products of firm j) when the wholesale prices p^w_{jt} change. When the price caps do not bind, the following first-order condition (Equation 5) holds:

$$\sum_{m \in J^f} (p^w_m - c_m) \times s_{mt}(p^r(p^w), x, \xi; \theta) \times \frac{\delta s_m}{\delta p^w_j} + s_{jt}(p^r(p^w), x, \xi; \theta) = 0 \quad \text{for} \quad p^w_m < \bar{p}^w_m. \tag{5}$$

The first-order condition for products with binding price caps is given in equation (6):

$$\sum_{m \in J^f} (p^w_m - c_m) \times s_{mt}(p^r(p^w), x, \xi; \theta) \times \frac{\delta s_m}{\delta p^w_j} + s_{jt}(p^r(p^w), x, \xi; \theta) \geq 0 \quad \text{for} \quad p^w_m = \bar{p}^w_m. \tag{6}$$

Note that marginal costs cannot be backed out for products with a binding constraint ($p^w_m = \bar{p}^w_m$). In most cases, the calculation of counterfactual prices requires estimates for marginal costs. For the current exercise, this is not a major concern, because most products are priced below their price ceilings. In the case of a retail markup or a tax decrease, the best response for firms is to increase the wholesale prices for these products. However, if prices were strategic substitutes, it might be profitable for some of the firms to lower the prices of the products with binding price caps in response to their competitors' price increases. A BLP demand system with Bertrand-Nash pricing allows, in theory, that prices can be either strategic substitutes or complements. If all prices are strategic compliments,

the best response to competitors' price increases (cuts) is a price increase (cut).

In the existing literature, Dubois and Lasio (2018) estimate manufacturer markups under maximum price regulation in the anti-ulcer market in France. In their model, they estimate the marginal costs using data from unregulated markets in Germany and the United States. The approach in Dubois and Lasio (2018) does not require that the econometrician observes which products have binding price caps, but their approach does require that marginal cost estimates for every product in unconstrained markets are available. Fan and Zhang (2022) take a similar approach in an application to the cell phone markets in China. Using data from markets without price ceilings, they project their marginal costs on observable firm characteristics and estimate the empirical distribution of supply shocks. They then simulate and solve for the expected marginal costs for the products with binding price ceilings in regulated markets.

Unfortunately, I cannot follow either approach, even though I have data from four Nordic countries. The Dubois and Lasio (2018) approach is not feasible because only a subset of products sold in Finland is available in other Nordic countries. Furthermore, the Fan and Zhang (2022) approach is not appropriate because all Nordic countries either directly regulate pharmaceutical price ceilings or negotiate price caps with pharmaceutical manufacturers.

I overcome this limitation by using inputed marginal costs. To be more precise, I first regress the Bertrand-Nash marginal costs from equation (5) on observable firm and product characteristics. The model is presented in equation (7):

$$\log c_{jt} = \gamma Y_{jt} + \omega_{jt}. \tag{7}$$

where Y_{jt} consists of a constant, log package sizes, at set of ATC5, brand status and firm dummies and market fixed effects. The ω_{jt} represent the unobserved supply shocks that affect marginal costs. I estimate the marginal cost parameters $\hat{\gamma}$ with OLS and use these estimates to predict marginal costs $\hat{c}_{jt}$ for the products with binding price caps (equation 6). This means that I assume that the supply shocks ω_{jt} are mean zero and are orthogonal to Y_{jt} in the model. The difference from the approach Fan and Zhang (2022) is that I cannot estimate an uncoditional empirical distribution of the shocks to simulate the expected marginal costs. However, I

believe that my estimates still allow me to get reasonable estimates for the key interest of this paper: The passthrough of pharmacy markups and taxes.[14]

5.3 Passthrough and markups

I estimate the passthrough of retail markups and value-added taxes by computing counterfactual prices under different markup and tax regimes. My supply model closely follows the structure of Miravete, Seim and Thurk (2018, 2020) that explicitly model the transmission of markups and taxes from wholesale prices to retail prices. From equation (4), I obtain the following expression:

$$p^w = c - [\underbrace{\Omega}_{\substack{\text{Ownership} \\ \text{matrix}}} \times \overbrace{\Delta^{w'}}^{\frac{\partial s_m}{\partial p_j^w} \times \frac{\partial p^r}{\partial p^w}}]^{-1} \times s_{jt}(p^r(p^w), x, \xi; \theta). \tag{8}$$

Because the government sets the margins, the Δ^w term in equation (8), representing the demand derivatives with respect to wholesale prices, can be expressed as

$$\Delta^w = \Delta^d \Delta^p = \underbrace{\begin{bmatrix} \frac{\delta s_1}{\delta p_1^r} & \cdots & \frac{\delta s_1}{\delta p_J^r} \\ \vdots & \ddots & \vdots \\ \frac{\delta s_J}{\delta p_1^r} & \cdots & \frac{\delta s_J}{\delta p_J^r} \end{bmatrix}}_{\text{Demand Jacobians w.r.t price}} \times \begin{bmatrix} \frac{\delta p_1^r}{\delta p_1^w} & \cdots & \frac{\delta p_J^r}{\delta p_J^w} \\ \vdots & \ddots & \vdots \\ \frac{\delta p_J^r}{\delta p_1^w} & \cdots & \frac{\delta p_J^r}{\delta p_J^w} \end{bmatrix} \tag{9}$$

where all elements are known from the regulatory rules. The cross-derivates $\frac{\delta p_{j'}^r}{\delta p_j^w} = 0$, and the diagonal elements $\frac{\delta p_j^r}{\delta p_j^w}$ consist of the retail markup and the VAT. I know the markup function and the VAT rate:

14. Based on visual inspection, the inputed marginal costs seem to follow the same empirical distribution than the estimated marginal cost.

$$\frac{\delta p_j^r}{\delta p_j^w} = \begin{cases} \rho_1 + \tau & \text{if } p_{jt}^w \times \text{DDDs per package} \leq 9.26 \\ \rho_2 + \tau & \text{if } 9.26 \leq p_{jt}^w \times \text{DDDs per package} \leq 46.25 \\ \rho_3 + \tau & \text{if } 46.26 \leq p_{jt}^w \times \text{DDDs per package} \leq 100.91 \\ \rho_4 + \tau & \text{if } 100.92 \leq p_{jt}^w \times \text{DDDs per package} \leq 420.47 \\ \rho_5 + \tau & \text{if } p_{jt}^w \times \text{DDDs per package} > 420.47 \end{cases} \tag{10}$$

where ρ's are approximations of the derivative of the piece-wise markup function with respect to the wholesale price and $\tau = 10\%$ is the VAT rate for pharmaceuticals. The estimation of the passthrough elasticities of the markups and taxes for product j follows after a counterfactual simulation by calculating:

$$\psi_j = \frac{\overbrace{p_j^{New} - p_j^{Old}}^{\text{Price difference}}}{\underbrace{\Delta\left(\rho + \tau\right)}_{\text{Cost shock}} \times p_j^{Old}} \tag{11}$$

where the denominator denotes the price level under full passthrough. Thus, equation (11) compares the change in retail prices under two markup or tax regimes (new and old) and compares it to a case of full passthrough, that is, how much prices would have changed had the change in the tax rate been transferred to retail prices one-to-one. Note that this specification allows for both under- and over-passthrough, that is, rates of passthrough below and over 100% (Miravete, Seim and Thurk 2023).

5.4 Identification

I need instruments to identify the parameters related to price sensitivity, namely α and σ_α. I utilize two types of instruments. First, I construct Hausman-like instruments using price data from other Nordic countries. These instruments can be classified as "cost shifters", as they capture common shocks to supply across countries and markets. The second type of instruments consists of Gandhi and Houde (2020) differentiation instruments constructed from one of the exogenous product characteristics, the package size. This instrument is a so-called "demand

shifter", as it measures aggregate changes in the characteristics of competing products, which shifts the demand of the product in question. I do not construct any differentiation or BLP instruments from the other exogenous product chracteristics all of which are dummies. In practice, they would capture aggregate changes in the consumers' choice sets from product entry and exit, and in many cases they would be collinear with some of my fixed effects. Therefore, in total, I have four instruments in my use: Three Hausman-like instruments, and one differentiation instrument.

Ideally, my Hausman instruments would consist of the prices of the same products in other Nordic countries. However, most products are not sold in other countries, let alone in all of them. The typical case in the literature is to use simple molecule-level averages (Atal, Cuesta and Sæthre 2022), but the variation provided by such an aggregated measure is limited, especially if product and market fixed effects are included in the model. Therefore, I take a slightly more sophisticated approach that resembles the process of imputing marginal costs in Section 5.2. First, for packages that are sold in a neighboring country, I use its own price in the neighboring country as the value of the instrument. For the other packages, I rely on an imputation approach. To be more precise, I estimate the following hedonic regression where the dependent variable, log wholesale price, is regressed on a set of observables X_{jt}:

$$\log p_{jt}^{w} = \beta X_{jt} + \varepsilon_{jt} \tag{12}$$

where X_{jt} comprises a constant, package sizes measured in DDDs and a set of molecule, firm, time period, branded, and reimbursement dummies. I estimate the model for Sweden, Denmark and Norway, and use the estimated country-specific estimates $\hat{\beta}$ with Finnish data to predict the log prices for the products that were not on the market in the other countries. Finally, I use the exponentiated predictions as instrument values.[15] In practice, these predicted values represent a type of conditional mean for the prices of similar products sold in the neighboring country.

15. Using logs in estimation and converting them to levels is done due significant outliers in pharmaceutical prices across molecules.

My approach is similar in spirit to Barahona, Otero and Otero (2023) who study the Chilean market for breakfast cereals. They construct simulated instruments by regressing cereal prices to known input prices and fixed costs. Barahona, Otero and Otero (2023) then use the predicted prices as instruments for the actual prices. Compared to their instruments, my instruments are a combination of actual Hausman instruments and simulated instruments.

5.5 Estimation

Since my supply model does not directly yield marginal costs for all products, I estimate the demand and supply models separately. I estimate the demand side with the suggested best practices from Conlon and Gortmaker (2020). The model is first estimated using the instruments described in Section 5.4. Then, I estimate the Chamberlain (1987) and Reynaert and Verboven (2014) optimal instruments and solve the demand model again with them. These are the final results reported in Section 6. I use 1000 Halton draws to simulate the agents used in the integration over the individual choice probabilities.

I use the demand-side estimates to compute the marginal costs for products without binding price caps (equation 5). I use these marginal cost estimates to compute counterfactual prices by changing the diagonal entries inside the matrix Δ^p in equation (9). However, for these counterfactual prices, I impose the simplifying assumption that the demand jacobians Δ^d in equation (9) are fixed. With this assumption, I avoid solving the equilibrium prices from the full model. Therefore, my results should be interpreted only in the sense of a partial counterfactual simulation.

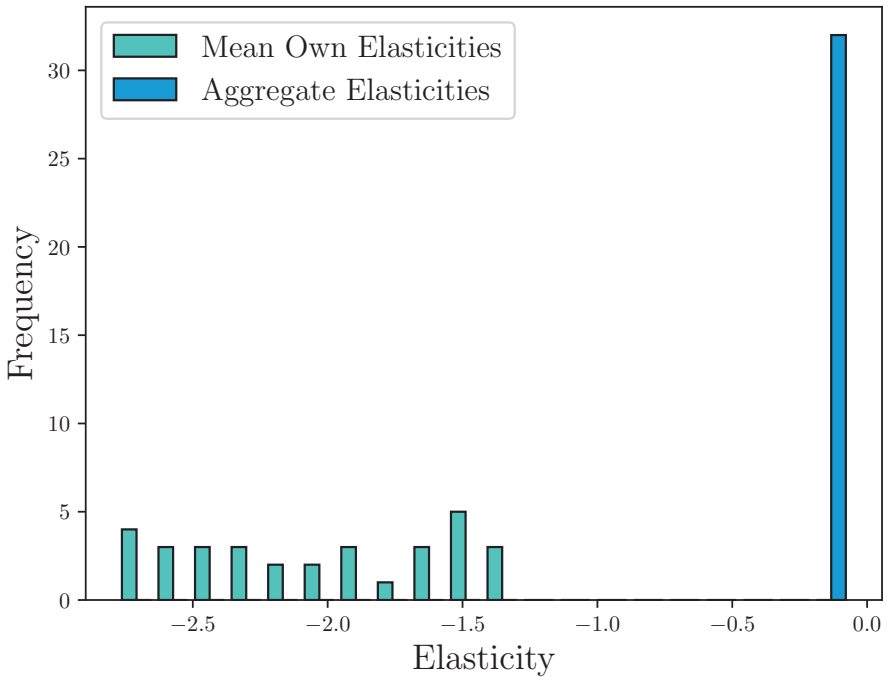
6 Results

6.1 Demand and Supply Estimation Results

The estimates of my structural model are presented in Table 5. My main specification is the log-normal random-coefficients model, but I also present the results from a simpler multinomial logit model and a standard random-coefficient model

for comparison. In all of the models, the coefficient for log package size is positive, meaning that, on average, consumers prefer larger package sizes over smaller ones. The price coefficients for the multinomial logit model and the standard random coefficient model are both negative. Note that the price coefficient for the log-normal model can be positive or negative as α_i is always strictly positive and is applied to negative prices during the estimation. Unlike in the standard random coefficient model, this ensures that demand is downward sloping for all consumers.

Figure 3: Own and Aggregate Elasticities



Notes: This figure presents the own price elasticity of demand of the log-normal random coefficient model of statin demand.

The multinomial logit model yields a mean own price elasticity of -0.95 and, most importantly, a mean marginal cost of -10 euro cents per DDD. The negative

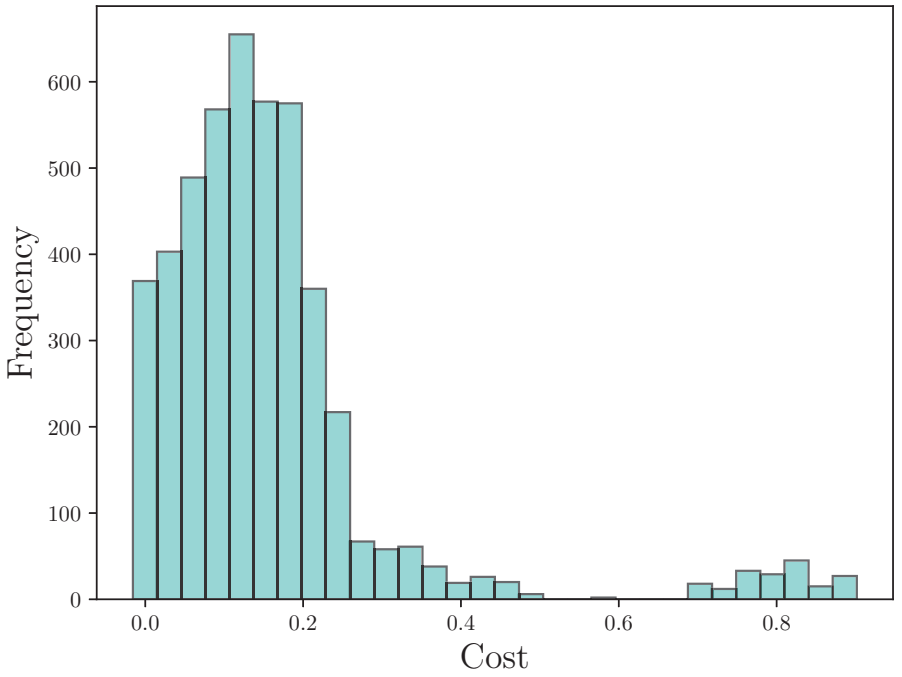
Table 5: Demand Model Results

Parameter	Logit	Random Coefficients Log-Normal	Random Coefficients Normal
Panel A: Linear Parameters			
α Prices	-1.82	1.88	-5.81
	(0.17)	(0.35)	(0.77)
β Log Package Size	1.63	1.18	1.16
	(0.06)	(0.14)	(0.11)
Molecule dummies	Yes	Yes	Yes
Year-Quarter dummies	Yes	Yes	Yes
Quarter dummies	Yes	Yes	Yes
Panel B: Nonlinear Parameters			
σ Prices		1.03	2.45
		(0.31)	(0.33)
Panel C: Additional Statistics			
Mean Elasticities	-0.95	-2.04	-1.99
	(0.03)	(0.08)	(0.06)
Mean Costs	-0.10	0.13	0.16
	(0.00)	(0.00)	(0.01)
Min Costs	-0.47	-0.05	-1.51
Share of Negative Costs	0.61	0.05	0.11
Mean Passthrough	-0.40	0.58	0.52
	(0.02)	(0.00)	(0.00)

Notes: This table presents the demand model estimates. Standard errors are in parentheses. Panel A presents the estimates on the linear parameters of the demand model, representing the mean tastes of the consumers. Panel B presents the non-linear parameters, representing the standard deviations of consumer tastes with respect to prices. Panel C presents the mean own prices elasticities of demand, marginal costsand the rates of passthrough for all products.

marginal costs are a clear indicator that the multinomial logit model yields price elasticities that are too small. The distribution of the marginal costs of the multinomial logit model is even more concerning: 61% products have negative

Figure 4: Distribution of Marginal Costs



Notes: This figure presents the Bertrand-Nash marginal costs from log-normal random coefficient model of statin demand.

marginal costs. I present the elasticity and cost distributions of the multinomial logit model in Appendix Section A.2.

The two random-coefficient models give very similar mean elasticities and marginal costs, but the underlying elasticity distributions differ significantly. The mean own-price elasticity of the log-normal model is -2.04 against -1.99 of the canonical BLP-model. The estimated marginal costs of both models are, on average, both positive, with the log-normal model producing an average marginal cost of 13 euro cents per DDD. Both models produce some negative marginal costs. For the log-normal random coefficients model, 5% of all marginal costs are below zero, and

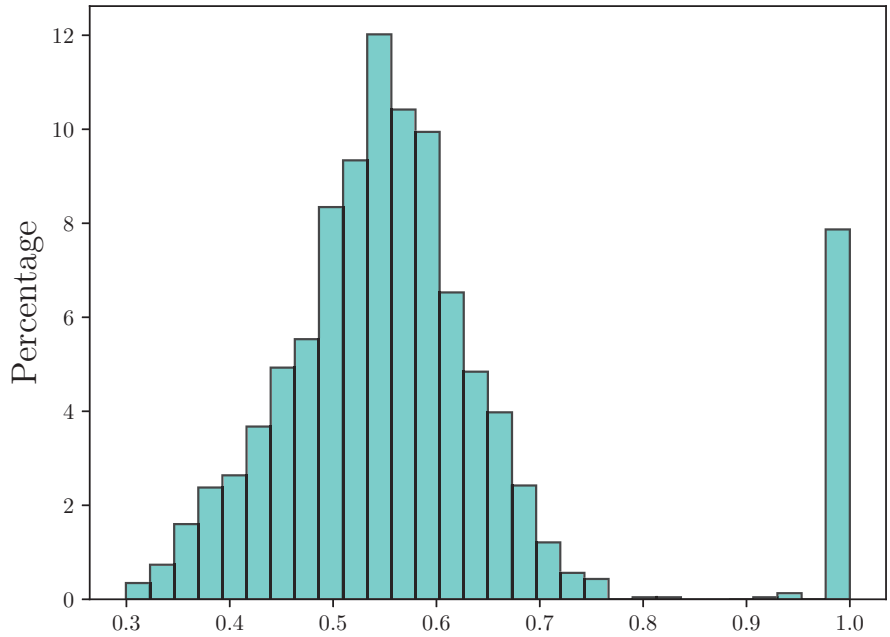
for the standard random coefficients model, negative marginal costs account for 11% of the products. I present the empirical distribution of the elasticity and marginal cost estimates for my preferred model—the log normal random coeffients model—in Figures 3 and 4. The distributions for the standard random coefficients model are provided in Appendix Section A.2. Even though the negative marginal costs are a clear minority, they can be seen as a concerning result, suggesting that even the log normal random coefficients model cannot produce large enough elasticities to rationalize the observed prices under Bertrand-Nash pricing. However, my elasticity estimates are in line with those in the existing literature. Using a similar demand model Kaiser, Mendez, Rønde and Ullrich (2014) estimated a median own price elasticity of 2.52 in the Danish statin market.

The mean own elasticities are in the range $[-3, -1.5]$ and are significantly higher in magnitude than the mean aggregate elasticities, which are concentrated below -0.5. The small and concentrated aggregate elasticities imply that estimated aggregate demand is almost completely inelastic and hardly varies between markets (quarters). However, this is likely due to the specification or market shares: In my estimations, I set the market share of the outside option to exactly 5%. This is for two reasons. First, I do not have access to prescription data that would allow me to estimate the number of prescriptions that are never fulfilled. Second, drug sales (even for statins) are highly seasonal, and fixing market potential in terms of the number of doses sold across markets would be limited by the market (quarter) with the highest sales.[16]

The mean passthrough rate—implied by the simulated prices and equation (11)—is 58% for the log-normal coefficient model and 52% for the normally distributed coefficient model. This means that approximately half of the decreases in 2014 in pharmacy markups were carried forward to consumer prices. The rest was taken up by the manufacturers, who increased their wholesale prices. The estimate is significantly higher than my reduced-form estimate of 28%, but because the sample consists of different drug markets, they cannot be directly compared. The mean passthrough rate of the logit model was negative 40%, further indicating its poor

16. The seasonality is most likely caused by the annual expenditure cap reimbursement system. This cap is reset at the beginning of January, so consumers above the threshold have an incentive to advance their purchases at the end of the year.

Figure 5: Distribution of Passthrough Rates



Notes: This figure presents the passthrough distribution of the log-normal random coefficient model of statin demand.

performance in this empirical exercise. I present the distribution of passthrough rates for my preferred model in Figure 5. The share of the products with binding price caps is visible in the graph as the mass just below one, representing full passtrough. For the other products with non-binding price caps, the distribution appears to be approximately normally distributed, suggesting a symmetrical spread of passthrough rates centered around the peak between the 50–60% rate range. The passthrough distributions for my other two models are presented in the Appendix Section A.2.

In Table 6, I decompose the passthrough rates from the log-normal model

by regressing the log passthrough rate on the exogeous product characteristics—molecule dummies and an originator-brand dummy—in my model. The base group for the molecule dummies is simvastatin. The first column presents the results for the full sample of products, and the second column presents the results for products without binding price caps, i.e. products whose marginal costs have not been imputed. For the first sample, the findings suggest that the passthrough rates are on average 5–20 percentage points larger for the other molecules than for simvastatin (base level). The differences in passthrough rates between statin molecules can be further analyzed in the context of Table 4. During the sample period, simvastatin products had a combined market share of more than 50%. Atorvastatin, which had the second highest total market share of 30%, had on average five percentage points higher passthrough rates than simvastatin. For the third largest statin, rosuvastatin, with a 14% total market share, the passthrough rates were on average 20 percentage points higher than those for simvastatin. The passthrough rates were on average 14 percentage points lower for the branded originator products, which is a surprising result, as one could expect the passthrough to be higher for the original branded product with a likely binding price cap and full passthrough. However, the result is mainly explained by the fact that of the 765 products with binding price caps, a majority of 556 are generics.

When conditioning on the non-binding price caps, as in the model in Column 2, the coefficients for the molecule dummies decrease significantly and, with the exception of rosuvastatin, they all lose statistical significance. The coefficient for the branded status is also significantly smaller in magnitude. However, the sign is still negative, implying that, on average, branded products with non-binding price caps had lower rates of passthrough than generics.

6.2 Counterfactual Simulations

Having calculated passthrough rates, I can calculate changes in revenues, manufacturer profits, consumer expenditure, VAT revenue, pharmacy profits, and in terms of quantities sold in DDDs when markups and the VAT rate are changed. Because my demand model abstracts away from regulation and reimbursements, the expenditure measurement is the sum of consumer copayments and government

Table 6: Passthrough Results

Dependent Variable:	Log(Passthrough)	Log(Passthrough)
Sample:	Full	No binding price caps
Model:	(1)	(2)
Variables		
Lovastatin C10AA01	0.0578*	-0.0280
	(0.0245)	(0.0152)
Pravastatin C10AA03	0.0722***	-0.0114
	(0.0184)	(0.0111)
Fluvastatin C10AA04	0.1230***	0.0042
	(0.0197)	(0.0144)
Atorvastatin C10AA05	0.0524***	-0.0131
	(0.0110)	(0.0069)
Rosuvastatin C10AA07	0.2030***	0.0267***
	(0.0107)	(0.0071)
Branded	-0.1475***	-0.0249**
	(0.0111)	(0.0086)
Fixed-effects		
Year-Quarter	Yes	Yes
Observations	2313	1548
R^2	0.2916	0.4007

Notes: This table presents the results from a regression model where the dependent variable is the logarithm of the estimated passthrough from Equation (11). The sample consists of the yeaars 2014–2017. The first column uses the whole data and the second column uses only data on products without binding price caps and whose marginal costs are computed directly from Equation (5).

reimbursements. I specify three different specifications. First, I estimate the effects of the 2014 reform, where pharmacy markups decreased. Second, I also conduct two other counterfactual simulations, where I demonstrate the effects of the VAT as policy tool in comparison to the regulated pharmacy markups. In these counterfactuals, I augment the markup decrease by increasing the VAT rate to either 10% or to 24% from 2014 and onward. In practice, this corresponds to a scenario in which the social planner cuts the markups but compensates for this by increasing the VAT rate for pharmaceuticals. The counterfactual VAT rates are indirectly imposed by EU regulation: Member states are allowed to have up to the three

VAT brackets, and in Finland these categories have been 10%, 14% and 24% since 2013.[17]

I present these findings in Table 7. These calculations are aggregated over the years, but I present the annual absolute and relative changes in Appendix tables A.3 and A.2. Starting from Panel A in Table 7, aggregate consumer savings during 2014–2017 were 5.3 million euros or 1.81% relative to the old markup system. Manufacturers increased their revenues annually by approximately six million euros, and their profits increased by five million euros. Quantities sold increased by roughly 0.27 percentage points. Pharmacy profits decreased by approximately ten million euros combined. Because consumer prices decreased and the effects on quantities were minimal, VAT revenues decreased by approximately 0.4 million in total. The results from Panel A imply that roughly half of the changes in pharmacy revenues benefited consumers (and the reimbursement system), while the other half was captured by pharmaceutical manufacturers. These changes are mainly in line with the average passhrough rates (Table 5), and the minor difference is explained by the differences in the prices and market shares of products. These calculations demonstrate how retail price regulation in the pharmaceutical sector is passed through the supply chain: The decrease in pharmacy markups in 2014 led to increases in manufacturer prices—and by extension—mostly import costs of drugs.

Panel B presents the results for the smaller VAT increase and Panel C presents the results for the larger tax increase. The contrast to the estimates in Panel A is stark: For the smaller tax increase, manufacturer revenues and profits increase two-thirds less, and for the larger tax increase, the aggregate revenues and profits decrease by 7.8 million and 6.1 million euros in total. Panel B also shows that consumer expenditure decreases by roughly 1.5 million euros, while tax revenues increase between almost ten million euros. For the larger tax increase, VAT revenue increases significantly more, raising 32 million euros more. However, consumer expenditure increases by 7.8 million euros. Pharmacy profits fall by ten million euros in the case of the smaller tax increase and by 21 million euros in the case of the larger tax increase.

The main difference between the results in Panel B and C is the change in

17. Not including the zero VAT rate.

manufacturer revenues and quantities. In Panel B, consumer prices still decrease relative to the pre-2014 regime, which is visible from the increase in total quantities sold. Manufacturer prices and profits also increase, as does government tax revenue. Because pharmacies lose, Panel B represents a transfer of rents from pharmacists to manufacturers, consumers, and the government. In Panel C, manufacturers no longer profit from the change in the regulatory regime. Consumers also lose, as their expenditure increases and statin consumption decreases relative to the old regime.

The results on consumer welfare should be interpreted in the context where the government pays roughly 70% of all prescription drug expenditure. Using this number as a benchmark for the numbers in Panel C, it can be approximated that aggregate consumer copayments increased by 2.3 million euros and government tax revenues net reimbursement costs increased by 26.4 million euros. Although this is only a crude calculation, it shows that within a generous tax-funded reimbursement system, higher drug costs due to VAT are not necessarily a concern. Furthermore, the government can always compensate for higher drug prices with other transfers or adjust the copayment caps within the reimbursement system. However, the reduced VAT rates increase the manufacturer's rents. In this context, the usual policy of small or even zero VAT rates in EU countries is ill advised.

My estimation results consider only the statin market, and although the external validity on the passthrough of pharmacy markups might carry on to other drug markets, they are not equilibrium calculations. First, they do not consider endogenous entry with respect to pharmaceutical manufacturers (product variety) or the profitability of pharmacies. Both are important for the counterfactual presented in Panel C in Table 7. A decrease in profitability could lead to decreased product variety and the network of pharmacies.

Second, although the public reimbursement system covers 70% of all prescription drug expenditures, there is significant heterogeneity between markets and consumers. An example of a large market without public reimbursement is the market for contraceptives. Using it as an example, an increase in consumer prices would lead to welfare losses that would be carried fully by a single demographic, women of reproductive age. Therefore, the results of my estimations should not be taken as a precise example of passthrough or the effects of counterfactual VAT policies.

Rather, they should be interpreted as evidence demonstrating that the incidence of regulated markups and taxes is not borne only by the consumers. Considering manufacturers' strategic responses to changes in taxes and regulations is important for evaluating policy effectiveness in markets with imperfect competition.

7 Conclusions

I study the transmission of pharmacy markups to retail prices and the relationship between retail markups and VAT rates in the Finnish pharmaceutical market. I use a DID strategy to demonstrate that pharmaceutical manufacturers responded to a decrease in pharmacy markups by increasing their wholesale prices. However, due to SUTVA concerns, these reduced-form estimates are likely to produce biased estimates of passthrough.

In my main analysis, I estimate a structural model of supply and demand using data from the Finnish statin market. My estimates imply that statin manufacturers benefited significantly from the policy change, increasing their revenues and profits 2014–2017. The results suggest that roughly two-thirds of the changes in pharmacy revenues benefited consumers (and the reimbursement system), while the rest were captured by pharmaceutical manufacturers. In two counterfactuals, I change the VAT rate and show that the government can offset the decreases in pharmacy markups and the resulting increases in wholesale prices by increasing the VAT rate of pharmaceuticals.

Table 7: Revenue Effects of the 2014 Reform and Subsequent VAT Changes

	Base	Absolute Change	Relative Change (%)
	Panel A: 2014 reform		
Quantity	767875.12	2106.80	0.27
Revenue	184568.45	6064.55	3.29
Profits	84551.05	4939.92	5.84
Expenditure	296385.70	-5373.04	-1.81
VAT Revenue	26944.15	-488.46	-1.81
Pharmacy Profits	77157.35	-9953.76	-12.90
Prices	36.55	-0.74	-2.03
	Panel B: 2014 reform + 14% VAT		
Quantity	767875.12	598.91	0.08
Revenue	184568.45	1802.66	0.98
Profits	84551.05	1517.39	1.79
Expenditure	296385.70	-1529.90	-0.52
VAT Revenue	26944.15	9266.21	34.39
Pharmacy Profits	77157.35	-10345.50	-13.41
Prices	36.55	-0.12	-0.33
	Panel C: 2014 reform + 24% VAT		
Quantity	767875.12	-3224.68	-0.42
Revenue	184568.45	-7762.02	-4.21
Profits	84551.05	-6089.72	-7.20
Expenditure	296385.70	7882.22	2.66
VAT Revenue	26944.15	31946.41	118.57
Pharmacy Profits	77157.35	-21858.22	-28.33
Prices	36.55	1.36	3.74

Notes: This table presents the aggregate changes in sold quantities, manufacturer revenues, manufacturer profits, consumer expenditure, VAT revenue and pharmacy profits between 2014–2017. Panel A presents the results for the actual 2014 markup change. Panel B presents the results for the 2014 reform with a VAT increase from 10% to 14%. Panel C presents the results for a VAT increase from 10% to 24%. Fixed demand jacobians are assumed. The first column presents the base case of the former markup regime. The absolute changes are in thousands of units and the relateive changes are in percentage points.

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A Appendix

The structure of the Appendix is as follows: section A.1 presents the data sources of my empirical analysis. Section A.2 presents the elasticity, marginal cost and Passthrough distributions for the multinomial logit model and the standard random coefficients demand model.

A.1 Data Sources

Table A.1 presents the data sources used in the analysis. The data from Sweden, Denmark, and Norway are used for the construction of Hausman-like instruments.

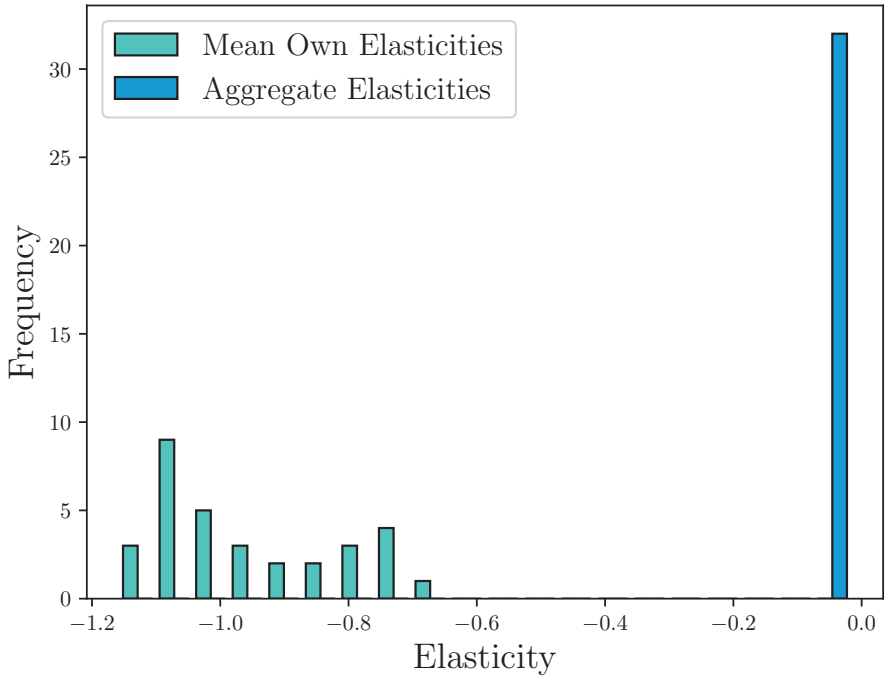
Table A.1: Data Sources

	Years	Source
Finland	1998–2017	FIMEA
Sweden	2006Q2–2017	IQVIA
Denmark	1991–2017	DLI-MI
Norway	2000–2018	Farmastat

Notes: FIMEA = Finnish Medicines Agency; PPB = (Finnish) Pharmaceutical Pricing Board; NOMA = Norwegian Medicines Agency; TLV = (Swedish) Dental and Pharmaceutical Benefits Agency.

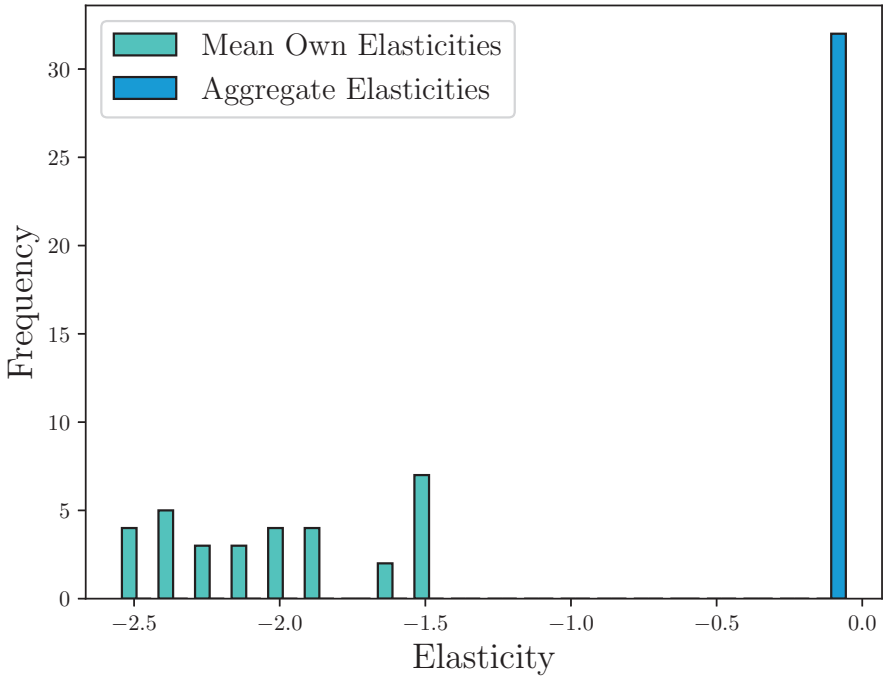
A.2 Elasticity, Cost and Passthrough Distributions

Figure A.1: Multinomial Logit Elasticities



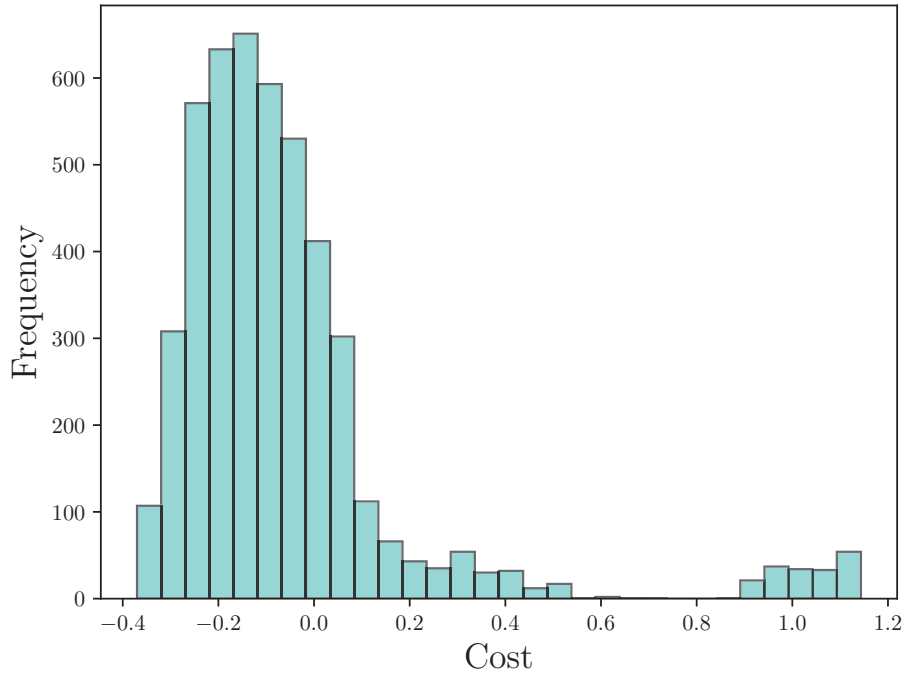
Notes: This figure presents the own price elasticity of demand of the multinomial logit model of statin demand.

Figure A.2: Random Coefficient Logit Elasticities



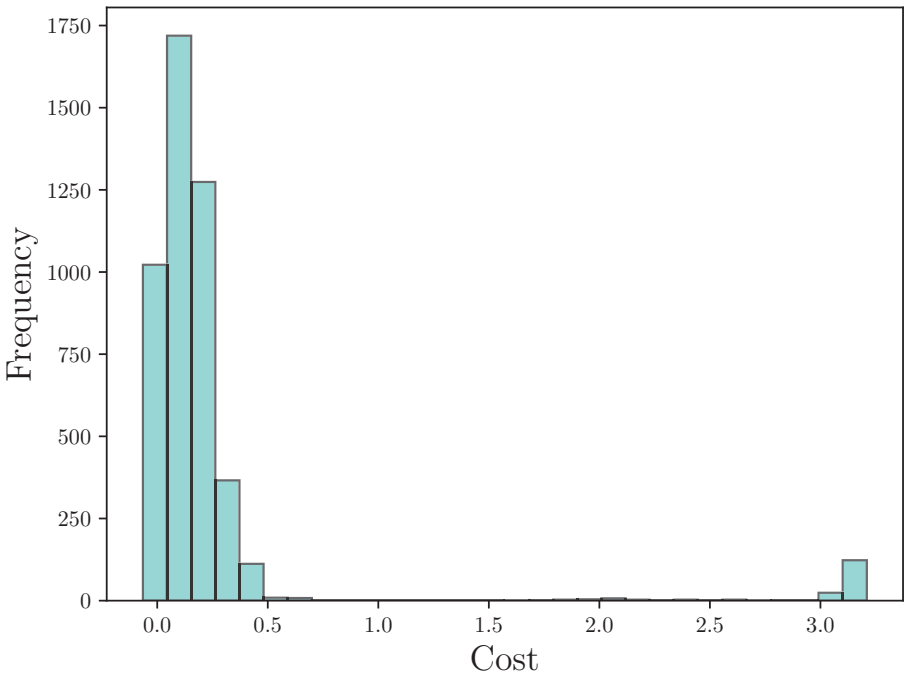
Notes: This figure presents the own price elasticity of demand of the standard random coefficient logit model of statin demand.

Figure A.3: Multinomial Logit Costs



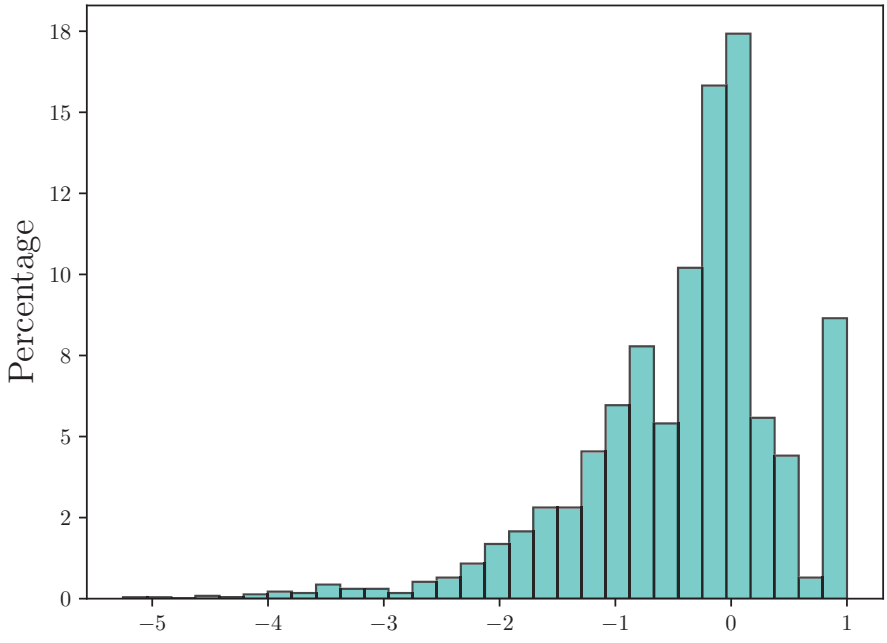
Notes: This figure presents the Nash-Bertrand marginal costs of the multinomial logit model of statin demand.

Figure A.4: Random Coefficient Logit Costs



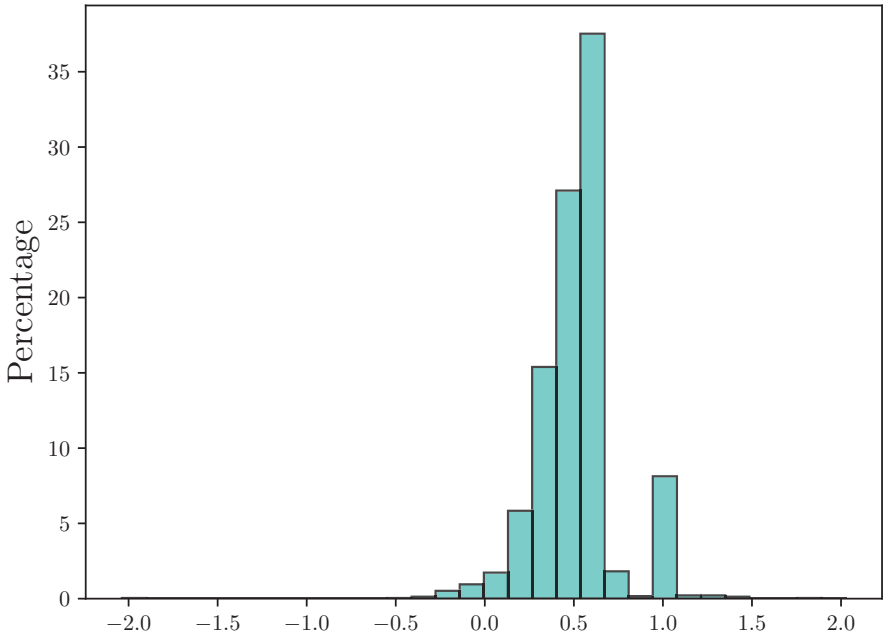
Notes: This figure presents the Nash-Bertrand marginal costs of the standard random coefficient logit model of statin demand.

Figure A.5: Multinomial Logit Passthrough



Notes: This figure presents the passthrough distribution of the multinomial logit model of statin demand.

Figure A.6: Random Coefficient Logit Passthrough



Notes: This figure presents the passthrough distribution of the standard random coefficient logit model of statin demand.

A.3 Financial changes

Table A.2: Annual Relative Financial Changes With VAT Increases

	2014	2015	2016	2017
Panel A: 2014 reform				
Quantities	0.25	0.29	0.30	0.26
Manufacturer Revenues	3.81	3.28	2.95	3.25
Manufacturer Profits	6.16	5.88	5.57	5.80
Expenditure	-1.60	-1.83	-1.97	-1.80
VAT Revenue	-1.60	-1.83	-1.97	-1.80
Pharmacy Profits	-13.05	-12.93	-12.84	-12.82
Prices	-2.32	-2.61	-2.74	-2.56
Panel B: 2014 reform + 14% VAT				
Quantities	0.09	0.09	0.08	0.06
Manufacturer Revenues	1.22	0.96	0.82	0.97
Manufacturer Profits	2.10	1.80	1.60	1.72
Expenditure	-0.55	-0.53	-0.51	-0.48
VAT Revenue	34.34	34.37	34.40	34.44
Pharmacy Profits	-16.39	-16.30	-10.78	-11.11
Prices	-0.64	-0.66	-0.64	-0.63
Panel C: 2014 reform + 24% VAT				
Quantities	-0.30	-0.42	-0.51	-0.44
Manufacturer Revenues	-4.55	-4.24	-3.98	-4.15
Manufacturer Profits	-6.94	-7.26	-7.23	-7.34
Expenditure	2.02	2.63	3.07	2.75
VAT Revenue	117.21	118.50	119.44	118.75
Pharmacy Profits	-29.01	-28.35	-27.89	-28.24
Prices	3.56	4.23	4.62	4.17

Notes: This table presents the annual relative financial changes. All units are in percentages.

Table A.3: Annual Absolute Financial Changes With VAT Increases

	2014	2015	2016	2017
Panel A: Base level				
Quantities	184329.74	189995.57	190795.45	202754.37
Manufacturer Revenues	37506.66	45865.38	51858.07	49338.35
Manufacturer Profits	19392.09	20980.39	21876.84	22301.73
Expenditure	60732.58	73635.10	82852.43	79165.60
VAT Revenue	5521.14	6694.10	7532.04	7196.87
Pharmacy Profits	16095.25	19159.65	21329.38	20573.07
Prices	38.12	44.74	50.51	45.87
Panel B: 2014 reform				
Quantities	452.19	545.59	581.17	527.86
Manufacturer Revenues	1427.22	1503.81	1529.58	1603.94
Manufacturer Profits	1195.46	1232.85	1218.60	1293.02
Expenditure	-971.05	-1344.22	-1630.63	-1427.15
VAT Revenue	-88.28	-122.20	-148.24	-129.74
Pharmacy Profits	-2099.99	-2478.03	-2738.16	-2637.59
Prices	-0.88	-1.17	-1.38	-1.17
Panel C: 2014 reform + 14% VAT				
Quantities	165.15	165.52	144.98	123.26
Manufacturer Revenues	458.36	440.90	424.49	478.91
Manufacturer Profits	406.31	377.52	350.78	382.78
Expenditure	-334.28	-393.51	-419.83	-382.28
VAT Revenue	1896.19	2300.48	2591.26	2478.27
Pharmacy Profits	-2638.46	-3123.33	-2298.32	-2285.40
Prices	-0.24	-0.29	-0.32	-0.29
Panel D: 2014 reform + 24% VAT				
Quantities	-561.15	-799.70	-965.07	-898.76
Manufacturer Revenues	-1707.22	-1943.53	-2063.21	-2048.06
Manufacturer Profits	-1346.41	-1523.48	-1582.70	-1637.14
Expenditure	1227.93	1935.93	2543.51	2174.86
VAT Revenue	6471.21	7932.55	8996.21	8546.44
Pharmacy Profits	-4668.87	-5431.81	-5948.07	-5809.48
Prices	1.36	1.89	2.33	1.91

Notes: This table presents the annual absolute financial changes. All units but prices are in thousands.

Essay III

Jokelainen, Antto and Markkanen, Jaakko and Leppälä, Samuli and Siikanen, Markku and Sipiläinen, Matti and Toivanen, Otto. Free Entry and Social Inefficiency in Regulated Pharmacy Markets. *Unpublished manuscript*.

Free Entry and Social Inefficiency in Regulated Pharmacy Markets *

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Markku Siikanen Matti Sipiläinen Otto Toivanen

Abstract

We study entry deregulation in the Finnish pharmacy market where prices, markups, and the number and location of pharmacies are regulated. Our counterfactual simulations show that the number of pharmacies increases substantially, particularly in urban areas. Although almost all consumers benefit, rural areas and areas with older populations benefit less. The increase in aggregate consumer surplus is dominated by significant decreases in pharmacy profits and government tax revenue. As a result, free entry turns out to be socially excessive. The prevailing entry restrictions may thus work reasonably well from a total welfare perspective, but with distributional consequences: They benefit incumbent pharmacists at the expense of customers.

Keywords: *entry regulation, deregulation, pharmacies, pharmaceuticals, welfare*
JEL-Classification: *L43, L81, R12*

*Author contributions: Jaakko Markkanen and Antto Jokelainen contributed equally to this work and are listed as co-first authors. The remaining authors are listed in alphabetical order. Antto Jokelainen: Aalto U. and Helsinki GSE, antto.jokelainen@aalto.fi. Jaakko Markkanen: ETLA, Aalto U. and Helsinki GSE., jaakko.markkanen@etla.fi. Samuli Leppälä: FCCA, samuli.leppala@kkv.fi. Markku Siikanen VATT and Helsinki GSE, markku.siikanen@vatt.fi. Matti Sipiläinen: FCCA, matti.sipilainen@kkv.fi. Otto Toivanen: Aalto U., Helsinki GSE and CEPR, otto.toivanen@aalto.fi. We thank Chris Conlon, Paul T. Scott, Olli Ropponen, and seminar audiences at ETLA and NYU for comments. We thank Elsa Saario and Patrik Björkqvist for their outstanding research assistance and the OP Group Research Foundation for financial support. All errors are ours.

1 Introduction

The economic literature classifies barriers to entry as a distinct source of market distortions. However, the benefits of free entry depend on the intensity of competition. In markets where competition is limited, perhaps due to government intervention (e.g., price regulation), the potential gains from free entry may not be fully realized. Conversely, if each new entrant incurs fixed costs, restricting entry may be socially efficient, especially when increased entry does not lead to significant market expansion. Additionally, free entry may have distributional effects, increasing inequality by altering the division of economic rents—both between the industry and consumers and within firms and across different consumer segments. This is especially the case when firms are horizontally differentiated and consumers have heterogeneous preferences. In such markets, regulation of entry may benefit consumer segments that would be left without provision under free entry equilibrium.

We study the effects of removing entry barriers in a highly regulated industry: The Finnish pharmacy sector. As in many other countries, it is subject to strict regulations covering, for example, entry, pricing and markups, ownership, professional qualifications, and pharmacy locations. The presence of both entry and price regulation enables us to examine the effects of entry restrictions in a setting with limited price competition between pharmacies. We explore how the pharmacy network would change if existing entry restrictions were lifted while keeping other regulations intact and identify and measure the associated trade-offs. We also demonstrate how different demographic groups (old vs. young) and geographic areas (urban vs. rural) would be affected by deregulation.

We estimate a model of demand and supply that allows us to simulate a counterfactual where existing entry restrictions have been relaxed. First, we estimate a spatial demand model of pharmacy choice. We build on the model of Ellickson, Grieco and Khvastunov (2020) and tailor it to the Finnish pharmacy sector. Our most relevant changes are i) allowing unobserved heterogeneity in the distaste for travel through random coefficients, ii) using travel time as the measure for distance, and iii) including demographic variation in market potential. Second, as in Verboven and Yontcheva (2024), we use a production function approach to

model variable costs of operating a pharmacy business and estimate fixed entry costs following Eizenberg (2014). In the third part of our empirical analysis, we simulate a counterfactual scenario in which we relax entry restrictions.

Our demand estimates show that consumers dislike longer travel times but with significant heterogeneity across consumers. This suggests that entry into neighboring markets can attract less distance-sensitive consumers away from their local market. Furthermore, we find that substitution to and from the outside option is limited. This implies that new entry to the market results mainly in business stealing with relatively little market expansion. Out of the models we consider, a random coefficients nested logit (RCNL) model produces the most flexible substitution patterns: It allows for closer substitution between pharmacies compared to the outside good, and it relaxes the assumption of independence of irrelevant alternatives (IIA) of standard logit and nested logit (NL) models.

On the supply side, we estimate pharmacies' variable costs using a Leontief-form production function with labor and material costs as inputs. We deal with the potential endogeneity between unobserved productivity shocks and revenue by using predicted revenues from the demand model as an instrument. Our instrumental variable (IV) estimates imply non-negligible economies of scale for the labor inputs. To estimate pharmacies' fixed costs, we follow Eizenberg (2014) and use observed entry and exit decisions to back out the range of fixed costs that rationalize these decisions. However, because regulated entry results in a very low number of entries or exits, we instead rely on the incumbents' decision to remain in the market to estimate upper bounds of the fixed costs. We do this separately for urban and rural pharmacies and use different percentiles of the estimated distribution of (the upper bound of) fixed costs in our counterfactual simulation.

Our counterfactual simulation shows that the number of pharmacies increases substantially with free entry. In the regulated regime, there were 822 pharmacies in Finland in 2021 (Association of Finnish Pharmacies 2021). In the free entry scenario, we end up with 2 276 pharmacies, an increase of 180%. However, there is significant variation in entry rates between regions. Most of the new entry is focused on densely populated urban areas with already existing pharmacies. For most rural areas, the relaxation of entry restrictions does not result in significant changes in their pharmacy network. However, there are some sparsely populated

rural areas that lose access to nearby pharmacy services.

Almost all consumers benefit from entry deregulation as consumer surplus (CS) increases for 98% of the population. However, the benefits are unevenly distributed between different consumer groups and geographical areas, with young consumers and urban areas gaining the most. When we cross-tabulate changes in welfare and market concentration—measured by Herfindahl–Hirschman index (HHI)—we find that almost 1% of the population face a decrease in welfare despite having a simultaneous decrease in market concentration. This phenomenon can occur when consumers lose their local services and must travel to areas that are further away but also exhibit more competition within that area. On the other hand, for nearly 3% of consumers, both CS and market concentration increase, suggesting an opposite effect with the introduction of new local pharmacies. These findings illustrate that decreases in market concentration do not always imply improvements in consumer welfare, nor vice versa.

Although our simulations show that almost all consumers benefit from free entry, total welfare does not increase. Three main mechanisms explain why: First, most consumers do benefit but these benefits are small, with the average increase in CS being a modest 14%.[1] Second, each new pharmacy incurs an additional fixed cost, leading to a 188% increase in total fixed costs. Third, new entry induces very limited market expansion (the number of pharmacies increases by 178% whereas sales increase by only 8%), which leads to a significant decrease in average sales per pharmacy. This decrease results in the loss of economies of scale, causing further welfare losses. Our counterfactual leads to significant redistribution of surplus: Although the pharmacy industry suffers, the government bears most of the loss through lost tax revenue. Total annual welfare decreases by 76 million euros (7%), with consumers gaining 68 million (14%), pharmacies losing 42 million (28%), and the government losing 103 million (24%).

The primary motivation for entry regulation—ensuring sufficient access to pharmacies for all consumers—is not supported by our analysis: Entry regulation

1. Our CS calculation does not include welfare gains or losses from increased pharmaceutical use implied by market expansion. On one hand, one may argue that the increase is overconsumption from a medical perspective, but on the other hand, one could also interpret the increase to be pharmacologically effective use by distance-sensitive consumers who would otherwise forego their medical treatments.

does not necessarily produce a more equitable pharmacy network than free entry. However, it does appear to prevent the welfare loss caused by excessive entry. This efficiency gain coincides with a significant reallocation of surplus: Pharmacists and the government benefit from entry restrictions at the expense of consumers. As an alternative to entry regulation, excessive entry could be addressed through adjustments to pharmacy markups or taxation. Under price regulation, improving consumer welfare is challenging without inducing losses for the industry or the government. Allowing price competition could improve consumer and total welfare, but the outcome would depend on the specifics of the deregulation.

The regulation of the Finnish pharmacy sector is representative of the pharmacy regulations found in many other developed countries. In the European Union (EU), 18 member states regulate pharmacies in a way that resembles the Finnish system.[2] Furthermore, the type of counterfactual that we conduct—relaxing entry restrictions while keeping price controls in place—is a scenario that is based on actual pharmacy deregulation reforms in Europe during the 21st century (e.g., the deregulation of the Swedish pharmacy market in 2009).[3] Our results focus on a regulated market but they may also be relevant for regimes without entry regulation but with perceived problems with the geographical coverage of pharmacies, such as the United States of America (US), where an active discussion exists regarding so-called "pharmacy deserts" (e.g., Ying, Kahn and Mathis 2022; Catalano, Khan, Chatzipanagiotou and Pawlik 2024; Wittenauer, Shah, Bacci and Stergachis 2024). In addition, our results are not strictly limited to pharmacy markets. Any market that exhibits limited market expansion from competition, e.g., due to price controls or the absence of prices, may be susceptible to excessive entry. These types of markets can be found, for example, from sectors such as education, healthcare, energy, or infrastructure.

Our work is related to three strands of literature. We contribute foremost to the literature on entry and especially on restricted entry and deregulation. Previous empirical and theoretical analyses have documented that free entry can be excessive when firms have market power. Competition from an additional entrant may reduce

2. See Online Appendix Table B.1 for details on restrictions related to the number of pharmacies, the ownership of pharmacies, and horizontal and vertical integration in the EU.

3. See Online Appendix Table B.2 for a list of EU countries with deregulated entry but with remaining price controls.

prices due to increased competition (when prices are not regulated, as in our case); however, the new entrant may capture customers from incumbent firms, leading to social inefficiency through business stealing by increasing the industry's total costs via higher fixed costs and reduced economies of scale. Spence (1976), Dixit and Stiglitz (1977) and Mankiw and Whinston (1986) theoretically examine excessive entry. Berry and Waldfogel (1999) and Hsieh and Moretti (2003) are classical empirical analyzes documenting welfare distortions arising from free entry in the radio advertising and real estate markets. However, restricted entry has received less attention. Ferrari and Verboven (2010) provide a brief overview of empirical applications and modeling choices of restricted entry.

Three articles are particularly relevant to our work. Schaumans and Verboven (2008) study the Belgian pharmacy market using data on the number and location of pharmacies. They find more pharmacies and lower regulated markups when entry restrictions are removed. Although their context is similar, we use revenue and production cost data coupled with a flexible demand specification and focus on entry restrictions without price changes. Seim and Waldfogel (2013) and Verboven and Yontcheva (2024) examine market configurations after changes in entry restrictions. Seim and Waldfogel (2013) analyze the retail alcohol market in Pennsylvania, whereas Verboven and Yontcheva (2024) study the Latin notary profession in Belgium. Both find that entry regulation shifts surplus from the consumers to the industry, and that deregulation would increase total welfare. In contrast, our findings demonstrate that in markets where market expansion is limited, the gains for consumers may be smaller than the losses of the industry, implying a decrease in total welfare.

We contribute to the methodological entry game literature on simulating spatial entry games by developing a backward version of the Seim and Waldfogel (2013) sequential myopic entry (SME) algorithm. We call this the backward sequential myopic entry (BSME) algorithm. It produces outcomes that satisfy the same conditions as the original algorithm, but is at least an order of magnitude faster for large-scale problems.

The second literature to which we contribute is deregulation. Previous work has found that deregulation can increase efficiency, reduce costs, boost economic growth, and increase consumer welfare (Winston 1993, 1998). Our contribution

to existing industry studies on deregulation is that we study the distributional implications of relaxing a policy that is designed to protect consumers from harm.

Finally, our work is also closely related to the literature on local public good provision. Regulated pharmacies are responsible for providing essential public health services. This institutional setup has many similarities with the school and hospital network consolidation literature. School consolidation can force students to travel longer distances, and demand reallocation can lead to network changes with adverse impacts on student outcomes (Engberg, Gill, Zamarro and Zimmer 2012; Brummet 2014; Beuchert, Humlum, Nielsen and Smith 2018). Similarly, the previous literature has found that hospital service network consolidations can have heterogeneous impacts on patient outcomes. Consolidation can improve the quality of care, but increasing travel distances can reduce health outcomes (Fischer, Royer and White 2024; Avdic, Lundborg and Vikström 2024; Avdic 2016; Bertoli and Grembi 2017).

The remainder of the article is structured as follows. In Section 2, we present the relevant institutions and regulations. We introduce the data and present descriptive statistics in Section 3 and our demand model in Section 4. We devote Section 5 to presenting our supply model. Sections 6 and 7 present the entry game and the entry game results. We offer conclusions in Section 8.

2 Institutions

In this section, we explain the institutional background and market regulations related to pharmaceutical pricing and reimbursement in Finland. Finland is a sparsely populated Nordic country with a population of 5.55 million and a population density of 18 people per square kilometer (48 people per square mile). In Finland, consumers can buy pharmaceuticals (both prescription (RX) and over-the-counter (OTC) products) only from pharmacies.[4] Like many other EU countries, Finland regulates entry into the pharmaceutical retail sector. These restrictions

4. Pharmacies are brick-and-mortar stores but they can also sell pharmaceuticals through online delivery. However, the role of the online channel is very limited in this market: According to Kokko, Hyvärinen and Reinikainen (2024), the share of online sales was only 0.5% of all pharmacy sales in Finland. Therefore, we do not model this channel in our analysis.

are intended to ensure equitable access to healthcare services by maintaining the availability and quality of pharmacy services, particularly in rural areas.

Pharmacy regulation. Our definition of pharmacies includes only community pharmacies: We exclude hospital pharmacies.[5] Pharmacies are subject to strict quantity and location regulations that are applied throughout the country. We refer to these rules as the entry regulation. The Finnish Medicines Agency (Fimea), the regulator, decides the number of pharmacies in each municipality and the geographical locations where pharmacists can operate their pharmacies.

A pharmacy must be owned by an independent pharmacist who meets the educational (M.Sc. in Pharmacy) and work experience requirements set by the regulator. Each pharmacist may operate only one main pharmacy and up to three subsidiary pharmacies at a time. The regulator may permit pharmacists to own subsidiary pharmacies in situations where the regulator considers some area to require pharmacy services, but for which there are no prerequisites for an independent pharmacy.[6] In some cases, a pharmacy license can be conditional on the operation of a subsidiary pharmacy in a designated rural area. The legal status of being a main or a subsidiary pharmacy does not directly affect the quality of the pharmacy services. However, it may be correlated with other factors, such as shelf space or opening hours, that can affect the perceived quality by consumers. When the regulator identifies the need to establish a new pharmacy, it asks qualified pharmacists to apply and selects the most qualified pharmacist for the task.[7]

The vertical and horizontal organization of the pharmacy market in Finland is also highly regulated. Vertical integration between pharmacies, wholesalers, and/or pharmaceutical manufacturers is prohibited, and pharmacies are not allowed to form chains. The only exceptions to this rule are the Universities of Helsinki and Eastern Finland, which are permitted to operate their own pharmacy chains due to historical reasons and their role in providing pharmacy education.

An important institutional feature is the dual role of pharmacists. As the owner,

5. Hospital pharmacies cannot sell pharmaceuticals; they can administer drugs free of charge for immediate use or for the start of outpatient care. See Finnish Medicines Act Section 7 65 §.

6. For detail on subsidiary pharmacies, see the Finnish Medicines Act 395/1987 52§.

7. The application form and basic rules can be found on the web-page of the regulator, Fimea. The key categories are 1) previous experience in pharmacies and pharmaceutical services and 2) relevant studies and management skills. The available materials do not give any indication on how the various aspects are weighed in the choice of the pharmacist.

a pharmacist is the residual claimant. In addition, a pharmacist can work in the pharmacy as a staff member. This dual role is particularly significant for small pharmacies, where the labor input from the owner can result in relatively low reported labor costs relative to turnover.

During our observation period (2021), pharmacists faced regulated markups: The retail prices of RX and OTC pharmaceuticals were given by a government-dictated piecewise linear function of the wholesale prices.[8] Implicitly, price competition for pharmaceuticals occurs at the wholesale level. For non-pharmaceutical products and services, pharmacies are allowed to set prices freely. In 2022, non-pharmaceutical sales were around 7% of the total private pharmacy turnover excluding Value Added Tax (VAT) (Kokko, Hyvärinen and Reinikainen 2024).

Pharmacies are not subject to the standard corporate tax; instead, they are taxed through a revenue-based pharmacy tax. The pharmacy tax applies to the total revenue from all pharmacies owned by the same pharmacist, including the main pharmacy and its subsidiaries. We demonstrate the differences between standard business taxation and pharmacy taxation in Appendix A.1. In addition to pharmacy tax, pharmaceutical sales are subject to 10% VAT. Pharmacists can engage in legal tax planning by establishing a limited liability company as a side-business for selling non-pharmaceutical products and services. In 2024, 38% pharmacists had established such a side-business. In our analyses, we do not model the tax effects of these side-businesses.

All in all, Finnish pharmacy regulations are in line with the international practice: Of the 27 EU countries, 19 (70%) regulate the number, 22 (81%) the location, 11 (41%) the ownership, nine (33%) the horizontal and 16 (59%) the vertical structure of pharmacies, and all but two the education of the pharmacy owner. We illustrate in Online Appendix B.2 Table B.1 that the pharmacy regulations currently used in Finland are also commonly used in other EU countries.

Wholesale price regulation. Pharmaceutical manufacturers compete with each other in the wholesale market. Manufacturers face a product-specific maximum wholesale price for reimbursed pharmaceuticals, but are allowed to freely set

8. Table A.1 in Appendix A.1 describes the pricing formula used during the year of our study. Since April 2022, the pricing of OTC products has been partly deregulated with a maximum retail markup instead of a direct pricing formula.

wholesale prices for OTC and RX drugs that are not included in the reimbursement system.[9] Manufacturers have to commit to uniform national wholesale prices. The purpose of the uniform prices is to guarantee equal prices throughout the country. Together these uniform wholesale prices and regulated pharmacy markups imply uniform retail prices for pharmaceuticals across pharmacies.

Reimbursement policy. In Finland, pharmaceuticals are reimbursed. Consumers can receive a reimbursement of 40%, 65%, or 100% of the retail price of the product, and the annual out-of-pocket (OOP) expenditure on reimbursed pharmaceuticals is capped. During our sample period (2021), price regulation incentivized consumers to substitute to an identical but cheaper product.[10]

3 Data

3.1 Data Sources

Our data come from several sources. Most of the spatial information is derived from the Statistics Finland Grid Database, which we refer to as "the grid data". This data divides Finland into 250m×250m cells and includes information on the population and age structure of the entire country. We assume that the representative consumers in our demand model and simulations reside at the centroid of the cells.

Our data on pharmacies and their financial statements are obtained from Fimea. The data contain standard accounting information on pharmacy profits and sales of RX and OTC pharmaceuticals. The balance sheet information also contains information on the cost structure and cost components of individual pharmacies. The data allow us to distinguish between labor, rental, and pharmaceutical wholesale purchases. We obtain pharmacy locations from the addresses reported in Fimea's pharmacy registry, and geocode these addresses to coordinates with OpenStreetMap data. We complement pharmacy data with pharmacy visit and expenditure data at the postal code level from the Finnish Social Insurance Institution (Kela).

9. We present a more detailed overview of the regulations in Appendix Section A.1.

10. Kortelainen, Markkanen, Siikanen and Toivanen (2023) provides further details on pharmaceutical price regulation in Finland.

We supplement these data with several publicly available data sets. First, we use cell-level information on the community structure and urban/rural classification from Finnish Environment Institute (SYKE). Second, we use open access information on local amenities (e.g., nearby grocery stores and health centers) from various OpenStreetMap contributors. These data are complemented with postal code-level population data from Statistics Finland's Paavo database. We allocate pharmaceutical expenditures evenly into cells within each postal code area. Lastly, for the geographical presentation of our results, we use country boundaries from EuroGeographics, a 1 km $\times$ 1 km population grid from Statistics Finland, and the Helsinki metropolitan area map from the city survey services of Helsinki, Espoo, Vantaa and Kauniainen. We present the full list of our data sources in the Online Appendix Section B.3.

We calculate the distances between cells, pharmacies, and potential entry locations using travel time by car, measured in minutes.[11] Therefore, throughout the article, 'distance' refers to travel time.

3.2 Descriptive Statistics

Table 1 presents descriptive statistics in two panels. Panel A displays cell-level information on consumers. On average, the cells are sparsely populated rural areas with middle-aged residents. We define the choice set of a cell to include all pharmacies within 45 minutes of the cell.[12] The average driving time to the nearest pharmacy is about 13 minutes and the average choice set size is close to 20 pharmacies. Kela expenditure is the per capita expenditure on RX drugs which we observe at a postal code level. We use the Kela expenditure to bring geographical (and implicitly demographic) variation in market potential to our demand model.[13]

Note that all of these variables exhibit large variation and skewed distributions. To pick a few examples and comparing the 10th percentile to the 90th, population increases 33 times; expenditures double; and the number of pharmacies within the

11. Using distance rather than travel time has been a concern in the literature on pharmacy deserts (Ying, Kahn and Mathis 2022).

12. See Online Appendix Subsection B.4 for further details on travel time computation.

13. In the demand model, we also add a fixed 50 euros to Kela expenditure to represent the missing OTC expenditure. This also helps us deal with areas where Kela expenditure is zero.

choice set increases by a factor of 23. Only 9% of cells are urban.

Table 1 Panel B summarizes the key characteristics of the existing pharmacies.[14] Most pharmacies are located in sparsely populated areas, as indicated by the average population density being double the median population density. Although job density in pharmacy cells is lower than population density, nearby jobs could potentially increase the demand for some pharmacies. 35% of existing pharmacies are located in an inner city area and almost 60% of the pharmacies have a supermarket nearby. Most of the existing pharmacies are main rather than subsidiary pharmacies and only 2% of the pharmacies belong to the Yliopiston Apteekki (YA) chain operated by the University of Helsinki.[15] Only 20% of the pharmacies have a nearby mall and 26% of pharmacies have a nearby health center. The average pharmacy sold pharmaceuticals worth 3.32 million euros, but the variation is large.

Table 1 panel C summarizes the key financial characteristics of the existing pharmacies used in production function estimation. This sample only contains roughly half of the existing pharmacies because pharmacies report their financials (excluding sales) together for the main pharmacy and the subsidiaries (see Section 2 for additional details). Therefore, we have limited our sample to only those pharmacies that have no subsidiaries.[16] The pharmacies in our sample also have slightly higher average sales than the entire population. Table 1 panel C shows that for an average pharmacy, material costs, which mainly consists of wholesale costs of pharmaceuticals, are the largest cost component, whereas labor and capital costs are much more modest. Material costs increase more rapidly than labor or capital costs when comparing distribution tails (P10 versus P90). Average profits net of material costs are slightly above €1M; profits net of labor and capital costs, as well as taxes, are €0.15M. The price-cost margin, defined as (Pharmaceutical sales - Material costs)/Pharmaceutical sales, is, on average, close to 30%. Deducting (variable) labor and capital costs leads to an average price-cost margin of 14%.

Figure 1a shows the structure of the current pharmacy network in Finland

14. Note that the locations of existing pharmacies are strictly regulated by Fimea, so it may be possible that the existing locations are not the most profitable locations for pharmacy operations.

15. The University of Eastern Finland Pharmacy is also included in the YA dummy.

16. We also exclude pharmacies that have significant amount of non-consumer sales, had an entry, exit or ownership change during the year, report zero capital or labor costs, or are one of the university pharmacies.

and Figure 1b provides a detailed view of the pharmacy network in the Helsinki (capital) area, the most densely populated area of the country. Pharmacies are evenly distributed throughout the country (Figure 1a), except in Northern and Eastern Finland, which are sparsely populated areas. Large cities have many pharmacies. Most pharmacies in Helsinki are located in densely populated areas with good access to different modes of transport (Figure 1b).[17]

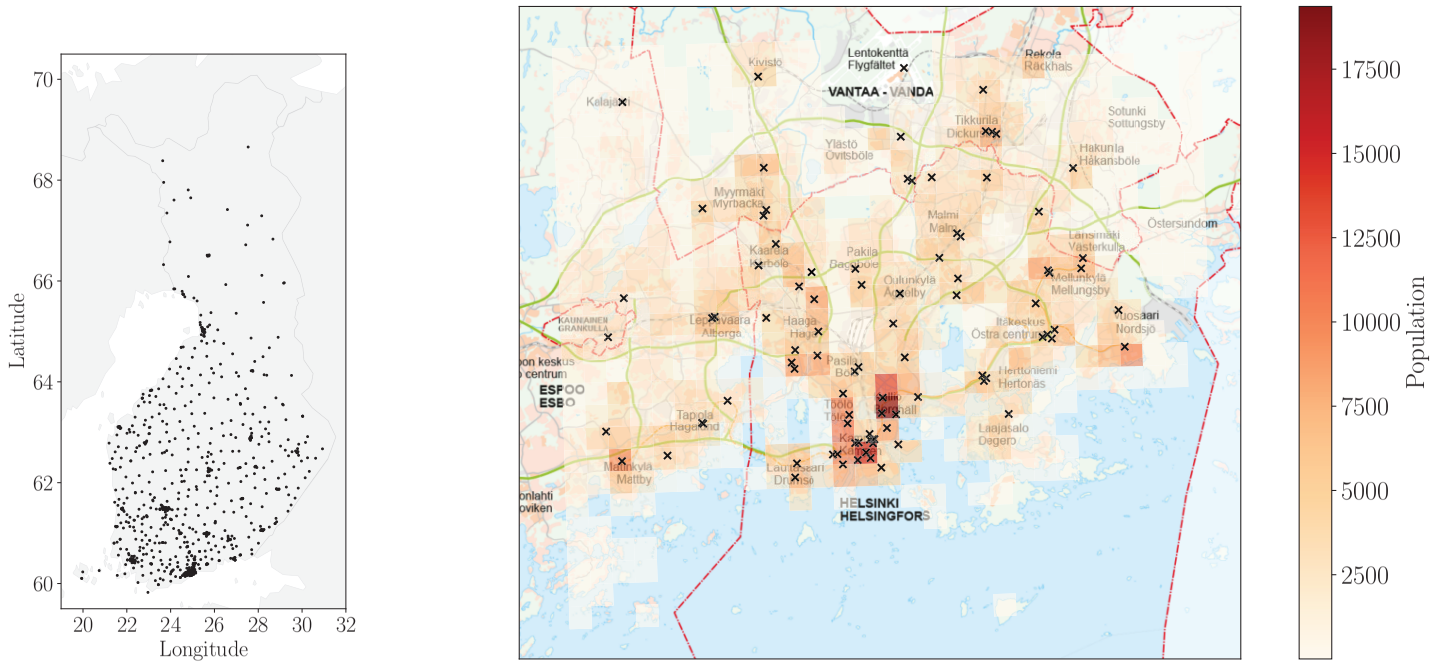
17. We exclude the pharmacy at Helsinki International Airport and any pharmacies that were founded during the calendar year, resulting in an incomplete accounting year, from the sample.

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	P10	P50	P90	N
Panel A: Cell characteristics						
Population	17.02	60.18	1.00	3.00	33.00	321950
City area	0.09	0.29	0.00	0.00	0.00	321950
Distance	13.18	12.23	3.63	10.91	24.13	321950
Choice set size	19.66	21.79	3.00	13.00	46.00	321950
Kela expenditure	453.52	139.49	306.90	440.63	601.08	321950
Market potential	604.23	167.39	428.28	588.76	781.29	321950
Panel B: Pharmacy characteristics (Demand model)						
Pharmaceutical sales	3.32	3.21	0.72	2.45	6.61	818
Inner city	0.35	0.48	0.00	0.00	1.00	818
Outer city	0.13	0.33	0.00	0.00	1.00	818
Rural center	0.08	0.27	0.00	0.00	0.00	818
Supermarket nearby	0.59	0.49	0.00	1.00	1.00	818
Mall nearby	0.21	0.41	0.00	0.00	1.00	818
Healthcare nearby	0.26	0.44	0.00	0.00	1.00	818
Public transport nearby	0.07	0.25	0.00	0.00	0.00	818
Population density	2.14	2.70	0.28	0.99	6.12	818
Jobs density	1.82	4.24	0.11	0.53	4.23	818
Main pharmacy	0.79	0.41	0.00	1.00	1.00	818
YA	0.02	0.15	0.00	0.00	0.00	818
Panel C: Pharmacy characteristics (Cost estimation)						
Pharmaceutical sales	3.85	2.21	1.45	3.48	6.74	402
Material costs	2.77	1.62	1.01	2.53	4.99	402
Gross profits	1.08	0.66	0.40	0.96	1.94	402
Price-cost margin	27.98	10.82	25.41	27.69	30.37	402
Labor costs	0.45	0.23	0.18	0.42	0.75	402
Capital costs	0.09	0.07	0.03	0.07	0.18	402
Net profits	0.15	0.08	0.06	0.14	0.25	402

Notes: This table presents descriptive statistics for consumer home cells (Panel A) and pharmacies (Panels B and C). Panel B includes the pharmacies used for estimating consumers' pharmacy choice, and Panel C the pharmacies used for estimating pharmacy cost function. All figures in Panel C, except the Price-cost margin, are in millions of euros.

Figure 1: Existing Pharmacy Network



(a) Pharmacies in Finland

(b) Pharmacies in Helsinki

Notes: The figure on the left plots the locations of all pharmacies in Finland. The figure on the right shows the locations of pharmacies and population densities in Helsinki. Sources for the maps: Fimea (2021), Nominatim and OpenStreetMap contributors (2024), Statistics Finland (2023), Helsinki City Survey Services, Cities of Espoo, Vantaa, and Kauniainen (2022) and EuroGeographics (2024).

4 Demand Model

We now develop and estimate a spatial model of pharmacy choice in Finland. We use the estimates of the model to rationalize the entry decisions of pharmacies in our counterfactual simulations.

4.1 A Spatial Model of Demand of Pharmacy Choice

We extend the discrete choice model of Ellickson, Grieco and Khvastunov (2020) by incorporating random coefficients. This extension is important for our entry counterfactual, as it relaxes the common IIA assumption. Our second extension is that we weigh the market potential with the postal code-level pharmaceutical expenditure data from Kela. This reflects the fact that some areas, mostly due to the age of residents, have significantly higher expenditure on pharmaceuticals. The weighting procedure allows our model to capture the exogenous variation in market potential and hence allows the model to match actual consumption patterns more closely.

A representative consumer i living at the centroid of cell t obtains indirect utility from spending at pharmacy s:

$$u_{ist} = \delta_{st} + \mu_{ist} + \varepsilon_{ist}, \quad u_{i0t} = \varepsilon_{i0t} \tag{1}$$

where we have normalized the mean utility of the outside good, u_{i0t}, to zero. With a NL specification,

$$\varepsilon_{ist} = \bar{\varepsilon}_{ih(s)t} + \left(1 - \rho_{h(s)}\right) \bar{\varepsilon}_{ist} \tag{2}$$

where $h(s)$ denotes the nests in the model where all inside goods are in the same nest and $\rho_{h(s)}$ is the nesting parameter to be estimated. This assumption implies that inside goods are closer substitutes to each other than to the outside good.[18] The common utility component in equation (1) is defined as

$$\delta_{st} = x'_{st}\beta_0 + \xi_{st}. \tag{3}$$

18. Values of $\rho_{h(s)}$ are consistent with utility maximizing behaviour when $0 \leq \rho_{h(s)} < 1$ holds. If $\rho_{h(s)}$ takes value 0, then the model collapses to a plain logit model.

We can further split x_{st} into factors related to the consumers' home cell t and factors related to the location of the pharmacy s. In our richest specification, the home cell specific variables in x_{st} include a constant, distance to the pharmacy (driving time), an indicator for whether cell t is an urban area or not, and interaction of the distance and the urban dummy.[19] For pharmacy-specific characteristics, we include a dummy for whether there is a supermarket, mall, health center, or public transport hub close to the pharmacy; population and job density in the pharmacy's vicinity; and dummies for the pharmacy being a main pharmacy or a university pharmacy.[20] In addition to the included variables, other potential pharmacy quality measures, such as pharmacy opening hours, waiting times, or service offerings, could also influence consumer utility. However, due to the lack of available data on these factors, we have not incorporated them into our analysis. We assume that the unobserved term ξ_{st} is orthogonal to all x_{st}.

Because, due to regulation, product-level pharmaceutical prices are uniform across all pharmacies, x_{st} does not include prices. Excluding prices from x_{st} only changes the size of the constant included to x_{st}. However, most pharmacies also sell non-pharmaceutical products, such as shampoo and cosmetics. Because we do not have detailed sales data on these products from pharmacies or other retailers, we make the crucial assumption that the choice probabilities of visiting a pharmacy are determined solely by pharmaceutical demand, with all other sales considered spillovers from that market segment. Throughout this article, when we refer to revenues R, we define them as pharmaceutical sales of OTC and RX products. We discuss the implications of this assumption in Subsection 4.2 and in Section 6.

The heterogeneous utility component is defined as:

$$\mu_{ist} = x'_{st} \left(\Sigma_0 \nu_{it} \right). \tag{4}$$

The indirect utility can also be written as $u_{ist} = x_{st}\beta_{it} + \varepsilon_{ist}$ with $\beta_{it} \sim \mathcal{N}(\beta_0, \Sigma_0)$. The additive ε_{ist} term is assumed to be i.i.d., drawn from a standard Type 1 extreme value distribution. This yields the familiar mixed multinomial logit model for the

19. Distance to the pharmacy is measured in minutes of travel time by car.

20. An amenity is considered to be near a pharmacy if it is within 200 meters of the pharmacy. Population and job density are calculated as an average of the cells within 500 meters of the pharmacy, and they are scaled to thousand inhabitants or jobs per one square kilometer.

choice probabilities:

$$\begin{aligned} p_{st}(\theta) &= \int \frac{\exp\left(\delta_{st} + \mu_{ist}\right)}{\sum_{k \in C_t} \exp\left(\delta_{kt} + \mu_{ikt}\right)} dF\left(\beta_{it}\right) \\ &= \int \frac{\exp\left(\delta_{st} + \mu_{ist}\right)}{\exp\left(u_{i0t}\right) + \sum_{k \in S_t} \exp\left(\delta_{kt} + \mu_{ikt}\right)} dF\left(\beta_{it}\right), \end{aligned} \tag{5}$$

with $\theta = (\beta_0, \Sigma_0)$. In equation (5), we define the choice set C_t of consumers in cell t as $C_t = S_t \cup 0$ where $S_t = \{s : d_{ts} \leq D\}$[21]. This means that the choice set of a consumers consists of i) pharmacies at most distance D away from the centroid of their home cell t, and ii) the outside good. D is defined in terms of travel time in minutes. The outside good corresponds to the consumer not buying pharmaceuticals from any pharmacy.

For our RCNL model, the choice probabilities are given by equation (6):

$$p_{st}(\theta) = \int \underbrace{\frac{\exp\left(\left(\delta_{st} + \mu_{ist}\right) / \left(1 - \rho_{h(s)}\right)\right)}{\exp\left(I_{ih(s)} / \left(1 - \rho_{h(s)}\right)\right)}}_{\text{Within nest probability}} \times \underbrace{\frac{\exp\left(I_{ih(s)}\right)}{\exp\left(I_i\right)}}_{\substack{\text{Probability of} \\ \text{choosing nest } h(s)}} dF\left(\beta_{it}\right) \tag{6}$$

with

$$I_{ih(s)} = \left(1 - \rho_{h(s)}\right) \ln \sum_k \exp\left(\left(\delta_{kt} + \mu_{ikt}\right) / \left(1 - \rho_{h(s)}\right)\right) \tag{7}$$

and

$$I_i = \ln\left(\exp\left(u_{i0t}\right) + \sum_h \exp\left(I_{ih(s)}\right)\right) \tag{8}$$

denoting the inclusive value term (Train 2009; Grigolon and Verboven 2014). The set $C_{t,h(s)} = \{q \in C_t : h(s) = h(q)\}$ is the set of pharmacies that are in the same nest per each choice set. In our RCNL setting, where one nest contains all pharmacies and the other contains only the outside option, $I_i = \ln\left(\exp\left(u_{i0t}\right) + \exp\left(I_{ih(s)}\right)\right)$. With the choice probabilities computed, the revenue that pharmacy s receives from consumers in cell t can be expressed as

21. In our estimations, we impose a minimum size of three for the choice sets.

$$\hat{R}_{st}(\theta, \alpha) = g(\alpha, r_t) \times N_t \times p_{st}(\theta), \tag{9}$$

where N_t is the number of consumers in cell t, and the term $g(\alpha, r_t)$ represents the potential per capita expenditure on pharmaceuticals. This means that consumers can spend up to $g(\alpha, r_t)$ euros on pharmaceuticals, and this spending is then divided into the inside goods and the outside good. Hence, the amount of pharmaceutical spending that we observe in the data is $g(\alpha, r_t)$ times the market share of inside goods. Our data and model would allow us to treat $g(\alpha, r_t)$ either as data, a parameter to be estimated, or both. We choose the latter approach, where we define $g(\alpha, r_t) = \alpha \times r_t$. We estimate α which represents market potential as a factor of observed pharmaceutical spending.[22]

Importantly, our choice model considers the utility of a single one-way trip to a pharmacy. Therefore, our welfare calculations are adjusted for the fact that consumers make multiple two-way trips to pharmacies. We incorporate this by using external data on the number of pharmacy visits displayed in the Online Appendix Subsection A.3. However, our model and interpretation are consistent a representative consumer visiting a pharmacy n_t times a year, because for each visit, they choose a specific pharmacy with the same probability $p_{st}(\theta)$. To see this, let us consider the following case: During visit j, representative consumer t spends an amount r_{jt}, with $j \in \{1, 2, ..., n_t\}$. The expected revenue for pharmacy s from cell t is $p_{st}(\theta) \times r_{1t} + p_{st}(\theta) \times r_{2t} + ... + p_{st}(\theta) \times r_{nt} = p_{st}(\theta) \times r_t$, where $r_t = \sum_j^{n_t} r_{jt}$. This example demonstrates how our expenditure data r_t can capture the variation in both the number of visits n_t and the expenditure per visit r_{jt}.

Defining $L_s = \{t : s \in C_t\} = \{t : d_{st} \leq D\}$ as the set of cells that have pharmacy s in their choice set, we can express the total revenue of the pharmacy as

$$\hat{R}_s(\theta, \alpha) = \sum_{t \in L_s} \hat{R}_{st}(\theta, \alpha). \tag{10}$$

The econometrician observes the revenues with a multiplicative measurement error e^{ζ_s}:

22. Term r_t includes the RX spending from Kela data added with a fixed 50 euros that reflect the share of OTC spending.

$$R_s = \exp(\zeta_s) \times \hat{R}_s(\theta_0, \alpha_0), \tag{11}$$

where θ_0, α_0 denote the true parameter values of the model. We estimate the model with non-linear least squares by minimizing the squared log-difference of the predicted revenue and the observed revenue:

$$(\hat{\theta}, \hat{\alpha}) = \underset{\theta,\alpha}{\operatorname{argmin}} \sum_s \left(\log\left(\hat{R}_s(\theta, \alpha)\right) - \log(R_s) \right)^2. \tag{12}$$

4.2 Demand Model Identification

The identification of our model parameters is based on the variation in the geographical distribution of population, demographics, pharmacy characteristics, and pharmacy revenues. We assume that consumers take their own and the pharmacy locations as given and that $(\epsilon_{its}, \zeta_s)$ are independent of pharmacy location and characteristics around the pharmacy, as well as consumer location and consumer location characteristics.

In the original Ellickson, Grieco and Khvastunov (2020) framework, the parameter α—denoting the expenditure share of total income potentially allocated to pharmacy purchases—is identified from variation in the total number of pharmacies in otherwise identical markets. In our application α denotes a multiplying factor such that the product of alpha and observed pharmaceutical expenditure is the amount of euros that a consumer could potentially spend on pharmaceuticals. So, if alpha is 1.5, then cells with observed expenditure of €100 and €200 have a market potential of €150 and €300, respectively. α is identified from the variation in the total number of pharmacies in observationally identical markets (consumer choice sets) and by observing the change in total revenue across all pharmacies. Increasing the number of pharmacies within choice sets may lead to substitution from the outside to inside goods and to redistribution of revenues between pharmacies. The identification of the demand parameters and the nesting parameter is similar to Ellickson, Grieco and Khvastunov (2020) and follows from the variation in pharmacy and consumer characteristics.

We estimate both the simple logit model with $\Sigma_0 = 0$, and the logit model with a random coefficient on the distance term. The random coefficient terms, σ, are

Table 2: Demand Model Main Results

Utility specification Model	Logit (1)	NL (2)	RC (3)	RCNL (4)
β Intercept	10.6436 ***		5.1818 ***	
	(2.6244)		(1.0359)	
β Distance	-0.2008 ***	-0.0288 ***	-0.2689 ***	-0.0341 ***
	(0.0165)	(0.0062)	(0.0268)	(0.0082)
β Dist. $\times$ Urban	-0.0310	-0.0032	-0.0224	-0.0003
	(0.0369)	(0.0052)	(0.0440)	(0.0056)
β Urban	-9.4842 ***	-0.4733 ***	-5.1704 ***	-0.5888 ***
	(2.6645)	(0.1170)	(0.9579)	(0.1245)
σ Distance			0.1381 ***	0.0149 **
			(0.0306)	(0.0049)
ρ		0.8651 ***		0.8706 ***
		(0.0296)		(0.0312)
α	1.0106 ***	2.0839 ***	1.1220 ***	2.1538 ***
	(0.0184)	(0.0371)	(0.0430)	(0.0450)
AIC	2410	2402	2403	2393
BIC	989	980	995	985
MSE	5.10e12	5.08e12	5.05e12	5.03e12

Notes: Distance refers to travel time by car. Model statistics: Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Mean Squared Error (MSE). Robust standard errors are presented in parenthesis; * p< 0.1, ** p< 0.05, *** p< 0.01.

identified from the variation in pharmacy locations between different cells and from the demographic variation surrounding pharmacy and consumer cells.

4.3 Demand Model Results

We present our demand model results in Tables 2 and 3, with Table 2 containing our main parameter estimates, including the constant, an indicator for urban cells, interaction between distance and urban cell indicator and the rest of the distance -related parameters, the estimates for the expenditure parameter α, and nesting parameter ρ and Table 3 the β pharmacy-level demand characteristics.

We estimate four models: 1) a standard logit model, 2) a NL model where all inside goods are in one nest and the outside good in another, 3) a random coefficients logit (RC) model with a random coefficient on the distance term, and 4) a RCNL model that incorporates both a nesting structure and a random coefficient on the distance term. As shown in Table 2, all specifications yield precise and negative estimates for the distance term. The RC model provides the most negative estimate at -0.269, with a corresponding random coefficient estimate of 0.138. The logit model yields an estimate of -0.201. The nested models show significantly smaller effects, with the NL estimate at -0.029 and the RCNL estimate at -0.034. The RCNL model's σ parameter is estimated at 0.015. The absolute ratio between the mean and standard deviation estimates (β and σ) is approximately 1.9 in the standard RC model and 2.3 in the RCNL model, indicating that RCNL has slightly fatter tails, implying stronger heterogeneity in consumers' distaste for distance.[23] The difference in the magnitude of parameter estimates between the nested and non-nested models is likely due to the nesting structure and limited substitution to the outside good. Consequently, the nesting parameter ρ obtains relatively high values at 0.865 for the standard NL model and 0.871 for the RCNL model.

Additionally, consumers living in urban areas have a higher probability of choosing the outside good. Because urban consumers have significantly larger choice sets than rural consumers, the model mechanically forces them to spend more on inside goods (due to non-zero choice probabilities). As a result, the urban dummy probably negates some of the effect of market expansion in urban areas caused by large choice sets. At the same time, estimates for the interaction of distance with a dummy variable for the consumer's home cell being in an urban area are small and imprecise across all models, implying that there is little difference in the average distaste for travel time between consumers in urban and rural areas. The AIC, BIC, and MSE metrics indicate that the RCNL model performs the best. We use its parameter estimates for our post-estimation statistics and as the basis for our entry game.

The market potential of a consumer is defined by the term $g(\alpha, r_t) = \alpha \times r_t$

23. The share of positive individual distance parameters $P(\beta_i > 0)$ for consumers in rural areas is $P\left(Z > \frac{0.2689}{0.1381} = 1.947\right) \approx 0.0258$ (2.58%) for the RCs model and $P\left(Z > \frac{0.0341}{0.0149} = 2.289\right) \approx 0.0111$ (1.11%) for the RCNL model. For consumers in urban areas, the share is a bit smaller due to negative interaction term between distance and urban dummy.

where r_t is the observed per capita pharmaceutical spending at the postal code level. Thus, the α's in Table 2 represent a multiplying factor for the size of the market potential. The standard logit model yields the smallest factor, 1.01, implying that the market potential is 1.01 times the observed pharmaceutical sales. The RC model has the second smallest value at 1.12. The two nested models provide significantly larger estimates, with the NL estimate for α at 2.1 and the RCNL estimate at 2.2. This is likely explained by the small substitution from the outside good to the inside goods imposed by the nesting structure and the large estimated nesting parameter.

We present the rest of our demand model estimates in Table 3. All models produce estimates that are robust across models, with the exception that nested models have systematically smaller magnitude than non-nested models, as was also the case with our main estimates. Furthermore, all of our estimates are consistent with economic intuition. First, consumers prefer pharmacies located near a supermarket, mall, health center, or public transit hub. Second, consumers dislike pharmacies located in densely populated areas or in areas with many workplaces. This could reflect that consumers do not want to visit pharmacies in city centers or commercial districts, but rather those pharmacies that are better accessible by car. Third, consumers prefer main pharmacies over subsidiaries, probably because main pharmacies are generally larger. Lastly, consumers have a strong preference for university pharmacies. This is expected, given that these pharmacies are part of the only significant pharmacy chain with a well-established brand.

We also calculate several post-estimation results based on our demand model.[24] We provide descriptive statistics at the representative consumer level on distance elasticities and HHI in Table 4. On average, the own distance elasticities are negative, around -3.6. The cross-elasticities for distance are positive but small, with a mean of 0.1 and a median of 0.02. We plot the distribution of the elasticities in Figure 2.[25]

24. Most of the formulas for the post-estimation results can be found in Ellickson, Grieco and Khvastunov (2020). Because we have included random coefficients in our model, we present the elasticity formulas for the RC and RCNL models in Appendix Section B.7.

25. The size of the elasticity matrix is N^2, where N is the number of representative consumer- or cell-to-pharmacy pairs. We plot the distributions for a random sample of 10,000 observations from the elasticity estimates.

Table 3: Demand Model Secondary Results

Utility specification Model	Logit (1)	NL (2)	RC (3)	RCNL (4)
		Pharmacy Characteristics		
β Supermkt Nearby	0.3572 ***	0.0479 ***	0.3680 ***	0.0471 ***
	(0.0517)	(0.0124)	(0.0540)	(0.0130)
β Mall Nearby	0.0407	0.0054	0.0307	0.0039
	(0.0595)	(0.0081)	(0.0618)	(0.0081)
β Health Nearby	0.0125	0.0013	0.0099	0.0012
	(0.0562)	(0.0076)	(0.0605)	(0.0077)
β Transit Nearby	0.0912	0.0125	0.1038	0.0120
	(0.1051)	(0.0146)	(0.1108)	(0.0144)
β Pop. Density	-0.0568 ***	-0.0077 *	-0.0660 ***	-0.0076 *
	(0.0172)	(0.0031)	(0.0180)	(0.0031)
β Jobs Density	-0.0238	-0.0032	-0.0229	-0.0028
	(0.0167)	(0.0023)	(0.0174)	(0.0023)
β Main Pharm.	1.0830 ***	0.1461 ***	1.1670 ***	0.1481 ***
	(0.0636)	(0.0323)	(0.0724)	(0.0354)
β YA Pharm.	1.5276 ***	0.2046 ***	1.5848 ***	0.1991 ***
	(0.1535)	(0.0519)	(0.1645)	(0.0528)
AIC	2410	2402	2403	2393
BIC	989	980	995	985
MSE	5.10e12	5.08e12	5.05e12	5.03e12

Notes: Model statistics: AIC, BIC and MSE. Robust standard errors are presented in parenthesis; * p< 0.1, ** p< 0.05, *** p< 0.01.

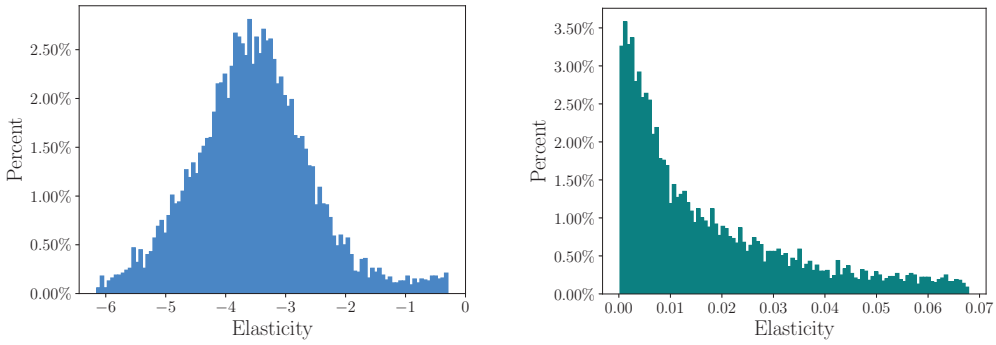
The HHI measures, calculated for each cell in Table 4, indicate that pharmacy markets in Finland are highly concentrated. Most markets exhibit extremely high concentration and limited competition, as reflected by a mean HHI of 4490 and a median of 4086. To further analyze market concentration, we aggregate HHIs from the representative consumer level to the postal code level using population as weights. The spatial variation in HHIs is illustrated in Figure 3. Panel 3a reveals significant spatial variation in the market concentration, with the most competitive markets (lowest HHIs) typically located in and around the largest

Table 4: Post Estimation Results

Variable	Mean	Std. Dev.	P10	P50	P90	N
Own Elasticity	-3.55	1.08	-4.82	-3.57	-2.31	6330641
Cross-Elasticity	0.08	0.23	0.00	0.02	0.15	271023390
HHI	4490.62	2546.34	1454.34	4086.45	8356.93	3007

Notes: This table presents post estimation results for our main demand specification. Elasticities are calculated with respect to driving distance in minutes. Own elasticities are computed for every cell × pharmacy pair, while cross-elasticities are computed for every cell × pharmacy × competing pharmacy combination in a choice set. HHIs are population-weighted averages of cell level HHIs aggregated to postal code level.

Figure 2: Elasticity Distributions



(a) Own Elasticities

(b) Cross-Elasticities

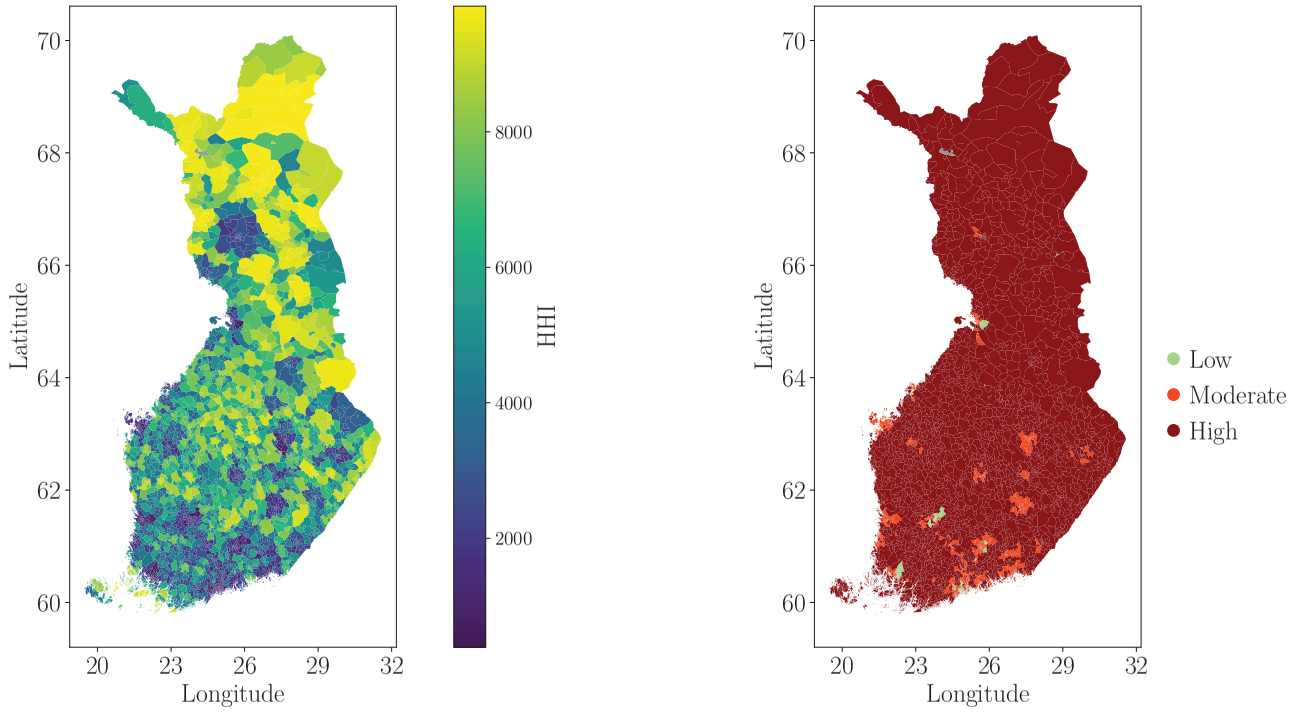
Notes: The figure on the left plots the distribution of cell × pharmacy own-elasticities with respect to distance in minutes. The figure on the right plots the respective cross-elasticities. Both distributions are plotted from a random sample of 10,000 observations from the full population. Extreme tails are excluded from the plots.

population centers.[26] However, as shown in Panel 3b, almost the entire country still falls into the 'High' concentration category, as defined by the EU merger guidelines. This finding points to the direction that the existing market structure, influenced

26. See Figure B.1 for the population distribution of Finland.

by entry restrictions, may be problematic from a competition law perspective, but this interpretation requires that market definition is not too narrow. Secondly, HHI can capture the closeness of competition only when products are not differentiated (Conlon and Mortimer 2021). Finally, an important point related to the use of HHI in a industry with extensive price regulation is that consumer harm arising from rising concentration occurs only through increased travel times.

Figure 3: HHI Maps



(a) Map of HHIs

(b) Map of HHI categories

Notes: The figure on the left shows the aggregated HHIs for postal code areas in Finland. The right figure categorizes them based on EU merger guidelines: 'High' (> 2000), 'Moderate' (1000–2000), and 'Low' (< 1000). Source: Statistics Finland (2021).

5 Supply Model

In this section, we introduce the supply model for pharmacy services. With the supply model, our aim is to identify variable labor and material cost parameters as well as fixed costs. We will use these parameters in the entry game to predict the costs of a pharmacy for a given level of demand. The total costs of a pharmacy consist of four parts: Material costs for the purchase of pharmaceuticals at wholesale prices, labor costs of employees, fixed costs (including capital costs), and taxes. We treat material costs, labor costs, and taxes as variable costs, and the rest as fixed costs. Therefore, fixed costs consist of capital costs but also, and probably mostly, of the opportunity cost of the owner, i.e., the pharmacist.[27]

5.1 Production Function

The regulations governing the Finnish pharmacy market restrict competition in terms of both pricing (of pharmaceuticals) and location choice. Pharmacies are required to order and supply a prescribed pharmaceutical product if it is unavailable. Minimum service quality is ensured by regulations on the education level of the pharmacy staff. There are some dimensions, such as opening hours and staff quality, in which pharmacies could compete quality-wise. However, evidence suggests that staff quality is not a primary issue: The existing literature on occupational licensing does not systematically find that licensing increases the quality of services or goods provided (Kleiner 2006; Angrist and Guryan 2008; Kleiner and Kudrle 2000; Barrios 2022; Farronato, Fradkin, Larsen and Brynjolfsson 2024). The institutional feature supporting our quality assumption is that in Finland there is no shortage of individuals who meet the educational and work experience requirements required for the pharmacy license.[28] It is also likely that such unobserved quality attributes do not have a first-order impact on our main objective: the location choice. Because of these reasons and unavailability of data, we do not include these factors in our

27. The owner's wage (or other reimbursement) is not included in the labor costs. As the owner is required to have a M.Sc. in Pharmacy and to be an experienced professional, they could pursue jobs in the public sector (e.g., the regulator, other health policy related institutions) as well as the private sector (e.g., pharmaceutical companies). Therefore, the opportunity cost is non-negligible.

28. Verboven and Yontcheva (2024) make the same argument related to service quality in their analysis of entry restrictions in the Belgian notary profession.

demand model, nor are they included in our cost estimations. As a result, we consider pharmacies to be cost-minimizers.

We assume that the variable costs of pharmacies consist of the wholesale costs of pharmaceuticals and labor costs. We measure these inputs in expenditure instead of physical quantities due to absence of quantity data. Although there are concerns in the literature about the use of expenditure measures (De Loecker and Syverson 2021), these are unlikely to apply to the Finnish pharmacy sector due to regulated wholesale and retail prices and due to relatively strict labor laws. We assume that the pharmacies' production function is

$$F(L, M) = \min\{\exp(A + \omega_L) \times L^{\kappa}, (B + \omega_M) \times M\} \tag{13}$$

and their objective is

$$\begin{aligned} \min_{L,\, M} \quad & C(L, M) = L + M, \\ \text{s.t.} \quad & F(L, M) \geq R \end{aligned} \tag{14}$$

In equation (13), the pharmacies have two inputs, labor (L) and material costs (M). Productivity is captured by three productivity parameters (A), (B) and (κ), and two productivity shocks (ω_L) and (ω_M). We observe L and M from the accounting data. We consider labor costs to consist of pharmacies' total labor costs (including rental labor) and material costs to consist of the wholesale costs of pharmaceuticals. It is reasonable to assume that pharmacies cannot substitute labor for material costs, or vice versa, and hence the production function form is Leontief.

The parameter A in equation (13) represents labor productivity. It can be thought of as the proportion in which labor is needed to be increased when output increases. Parameter κ represents returns to scale with respect to labor input. The interpretation of the parameter B in equation (13) is straightforward: $1 - B$ represents the mean markup of pharmaceuticals.[29] Note that we do not allow for returns to scale to material inputs due to the fact that material costs consist of

29. See the markups in Appendix Table A.1.

pharmaceutical wholesale costs that do not change as a function of bought quantity. The pharmacy-specific productivity shocks ω_L and ω_M capture differences in input use across pharmacies. These are potentially correlated with unobserved demand shocks and therefore with revenue R. For example, a pharmacy can employ more productive workers who work faster but also provide better service quality for consumers. Alternatively, pharmacy employees can provide better service quality only by being otherwise less efficient. Similarly with material costs, some pharmacies may serve areas that have higher markups than some other observationally similar pharmacies, hence implying correlation between R and ω_M. Equation (5.1) results in the following optimality conditions:

$$R = \exp(A + \omega_L) \times L^{\kappa} = (B + \omega_M) \times M. \tag{15}$$

By taking logarithm of the left side of equation (15) and solving materials M from the right side side of equation (15), this can be further transformed into:

$$\begin{aligned} \ln(L) &= \frac{1}{\kappa} \ln(R) - \frac{1}{\kappa} A - \frac{1}{\kappa} \omega_L \\ M &= \frac{1}{B + \omega_M} \times R. \end{aligned} \tag{16}$$

We use these equations to estimate the parameters A, B, and κ. Because unobserved productivity shocks may be correlated with revenues, the regressions potentially suffer from endogeneity. To deal with this, we use predicted revenues from the demand model as instruments, thereby assuming that the observables on the demand side are orthogonal to unobserved productivity shocks. Predicted revenue is a suitable instrument for dealing with the potential endogeneity problem related to productivity shocks, because the instrument is purely formed from the determinants of the pharmacy service demand. Instruments generated from the demand model are correlated with the observed output, but are uncorrelated with the unobserved productivity shock that is generating the potential endogeneity issue. These are the same identification arguments as in Verboven and Yontcheva (2024).

We present estimation results from equation (17) in Table 5. The cost model is estimated using data on 402 pharmacies, as we cannot separate the accounting

Table 5: Production Function Estimates

Estimator:	OLS		IV	
Model:	(1)	(2)	(3)	(4)
Dependent Variable:	$\ln(L)$	M	$\ln(L)$	M
Variables				
$\ln(R)$ or R	0.88***	0.72***	0.94***	0.72***
	(0.03)	(0.00)	(0.03)	(0.00)
Intercept	-0.35		-1.17***	
	(0.47)		(0.45)	
Observations	402	402	402	402
R^2	0.82	0.99	-	-
F-statistic	-	-	728.45	2857.56
Transformations				
Return to scale (κ)	1.14		1.07	
Productivity (A or B)	0.39	1.39	1.25	1.39

Notes: The point estimates and the standard errors are for the parameters in equation (16), and the transformations give the respective values in the first-order equation (15). The F-statistic represents the weak instrument test from Olea and Pflueger (2013) and Pflueger and Wang (2015) where the critical value for rejecting the null hypothesis with a significance level of 5% is 37.42. Robust standard errors in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01.

data on costs between main and subsidiary pharmacies operated by the same pharmacist. The production function parameters, which are transformations of the OLS or Two-Stage Least Squares (2SLS) estimates, are presented at the end of the table. First, focusing on labor, the estimates indicate notable returns to scale with respect to labor input. Additionally, the difference in the estimates and the transformed production function parameters demonstrate that failing to account for endogeneity results in biased estimates. The estimated returns to scale (κ) are smaller with 2SLS whereas the productivity (A) is conversely much larger. However, for material costs, the difference between OLS and 2SLS estimates is negligible.[30] Our instruments are strong, as shown by the large F-statistics and weak instruments tests.

30. The difference is not exactly zero. Rather, it is not visible because of rounding.

The endogeneity bias in labor inputs can be explained by the fact that pharmacies with smaller productivity shocks use more of the input in question. This behavior can be explained by the need to comply with industry regulations. Notice that the productivity term, derived from the constant in the estimation, differs significantly in magnitude between the OLS and 2SLS models for labor: the 2SLS estimate of A is more than three times larger than the OLS estimate. On the other hand, we do not observe practically any endogeneity bias in material inputs. This is natural in our setting because material inputs consist of wholesale costs of pharmaceuticals and the wholesale costs have a mechanical relationship with the pharmaceutical revenue due to regulated markups.

Lastly, the predicted (variable) costs for new entrants in our entry model can be obtained as a function of the predicted revenue, as shown in equation (17):

$$C(\hat{R}) = \underbrace{\left(\frac{\hat{R}}{\exp(A)}\right)^{\frac{1}{\kappa}}}_{\substack{\text{Predicted} \\ \text{Labor costs}}} + \underbrace{\frac{1}{B} \times \hat{R}}_{\substack{\text{Predicted} \\ \text{Material costs}}} . \tag{17}$$

5.2 Modeling Fixed Costs

Our approach to estimating fixed costs is based on Eizenberg (2014). The main idea behind the approach is to use observed entries and exits (or lack thereof) to back out the range of fixed costs that can rationalize these decisions. However, due to the extremely low number of entries and exits in the pharmacy market, we cannot use this information to tighten the bounds.[31] Moreover, due to the regulated nature of the industry, we lack data on the locations locations available for entry where no entrants were willing to enter. Therefore, all the information we have available is the decision of the incumbents to remain in the market. With this information, we can estimate an upper bound for the fixed costs but not a lower bound.

For the fixed cost estimation, we use the same 402 pharmacies that we used for production function estimation. This is because we lack accounting data for the rest of the pharmacies. We first calculate predicted revenues and demand shocks $\hat{\zeta}$

31. We also cannot be sure if the few exits that we observe are for economic reasons.

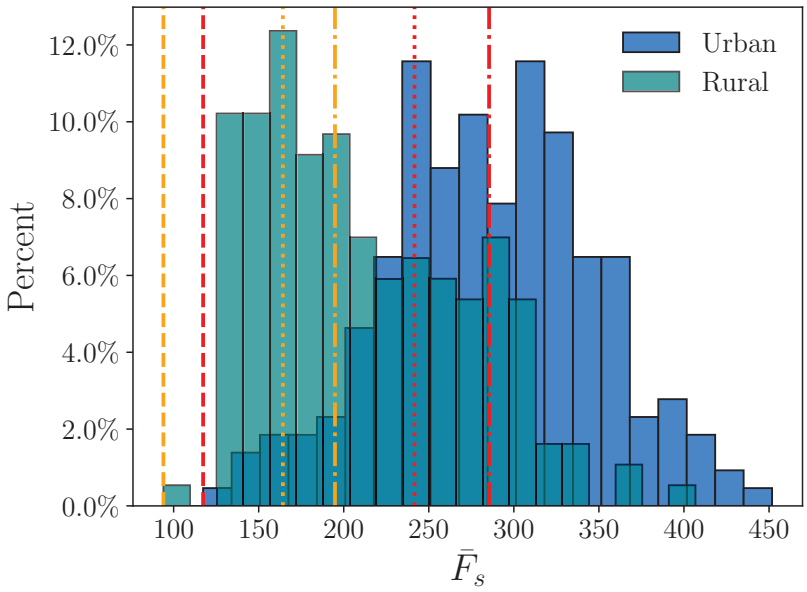
using our RCNL demand model estimates. Next, we use our production function estimates to obtain the productivity shocks $\hat{\omega}_L$ and $\hat{\omega}_M$. We then estimate the empirical joint distribution of these three shocks.

$$\Pi = \overbrace{\hat{R} \times \exp(\zeta)}^{\text{Revenue}} - \overbrace{\frac{1}{B+\omega_M} \times \hat{R} \times \exp(\zeta)}^{\text{Material costs}} - \underbrace{(\frac{\hat{R} \times \exp(\zeta)}{\exp(A)})^{\frac{1}{\kappa}} \times \exp(-\frac{\omega_L}{\kappa})}_{\text{Labor costs}} - \underbrace{T(\hat{R} \times \exp(\zeta))}_{\text{Taxes}} \tag{18}$$

Equation (18) illustrates pharmacies' gross profits (profits before fixed costs) as a function of predicted revenue ($\hat{R}$) and demand and productivity shocks (ζ, ω_L, ω_M). Following Eizenberg (2014), we take Y draws from the joint distribution of shocks and use these to calculate the gross profits for each pharmacy and each draw. We then average these gross profits over the draws to obtain expected gross profits for each pharmacy. Because these pharmacies choose to remain in the market, these estimates represent the upper bound of the fixed costs that rationalize the pharmacies' decisions. This procedure is detailed in Algorithm 3 in Appendix Subsection A.2.

The procedure above provides estimates for the fixed cost upper bounds for the locations of the 402 pharmacies. Figure 4 illustrates this distribution separately for pharmacies in urban and rural areas. To estimate fixed costs for counterfactual entry locations, we use the minimum of the fixed cost distribution as the fixed cost estimates for entrants. These costs are calculated separately for urban and rural locations, and Figure 4 depicts these estimates with dashed lines. The thresholds are €93,987.95 for rural areas and €117,321.20 for urban areas. The difference in costs between urban and rural locations can be attributed to variations in the opportunity cost of pharmacists (who tend to be older and more experienced in urban pharmacies) and in real estate expenses, with leasing property for a pharmacy being more expensive in urban areas than in rural locations.

Figure 4: Fixed Cost Estimates



Notes: The figure plots the fixed cost estimates for urban and rural pharmacies. Orange lines represent rural pharmacies, and red lines represent urban pharmacies. Dashed lines denote the minimum values (main specification), dotted lines indicate the 25th quantile, and dash-dotted lines indicate the median. Fixed costs $\bar{F}_j^s$ are denoted in thousands of euros.

6 Entry Game

In this Section, we describe how we simulate entry into the Finnish pharmacy market under a counterfactual deregulation of the entry restrictions. In our counterfactual, we keep the existing price regulation in place: New pharmacies can freely enter the market, but price competition between pharmacies remains absent. This allows us to study the effects of entry deregulation in a market with no price competition. Furthermore, this type of deregulation resembles past deregulation policies in Europe, where entry restrictions have been relaxed while price controls have remained in place. Online Appendix Section B.2 and Table B.2 describe the deregulation policies that have been implemented in the EU.

In our counterfactual, pharmacies are making entry decisions based on predicted profits:

$$\hat{\Pi} = \hat{R} - M(\hat{R}) - L(\hat{R}) - T(\hat{R}) - FC. \tag{19}$$

Here, $\hat{R}$ is the predicted revenue from our demand model for the given configuration of pharmacies, material costs (M) and labor costs (L) are obtained from the production function, T represents taxes and it includes the pharmacy tax and VAT, and FC is the fixed cost which is different for urban and rural areas. This profit measure is also our definition for producer surplus (PS) in welfare calculations.

We need to address how we will solve the counterfactual network of pharmacies. The issue is that solving the equilibria of a game of this size is computationally impossible. Instead, we follow the literature and use an algorithmic approach to achieve a configuration of pharmacies that approximates some equilibrium. To be precise, we rely on a SME algorithm, as suggested by Seim and Waldfogel (2013). This algorithm results in a configuration of pharmacies in which no pharmacy wants to enter or exit the market. This deviates from Nash equilibrium since some pharmacies may still want to change their location in the resulting configuration. Furthermore, the SME algorithm assumes that the entrants do not consider the actions of subsequent players and, therefore, are fully myopic. We discuss these features in detail in Subsection 6.1.

In our application, the size of the problem is notably larger than in previous applications that have relied on the SME algorithm.[32] Therefore, in our case, even the SME algorithm is computationally slow. To deal with this, we make two notable alterations. First, we limit potential entry locations to grocery stores. This reduces the number of potential entry locations from 300,000 to approximately 4,000.[33] Second, we introduce an alteration to the SME algorithm that improves computation time. The BSME algorithm is significantly faster, and it produces a

32. Verboven and Yontcheva (2024) analyzed 16,353 notary markets and 2,413 potential entry locations in Belgium, whereas Seim and Waldfogel (2013) used 3,125 census tracts in Pennsylvania. In contrast, our specification includes over 321,000 grid cells and approximately 4,000 potential entry locations.

33. Online Appendix Subsection B.1 provides a detailed explanation of how potential entry locations are defined and the rationale behind our selection. Online Appendix Figure B.2 illustrates potential locations in Finland and in the Helsinki metropolitan area.

configuration that satisfies the same conditions as the SME algorithm. We describe the SME and BSME algorithms below.

As discussed in Section 4, our demand model is estimated using pharmaceutical revenue. Accordingly, our demand model predicts the sales only for pharmaceuticals and not for non-pharmaceutical products, such as hair care products or cosmetics. In reality, pharmacies sell both of these and hence also the non-pharmaceutical products can affect their profitability. In our counterfactual, we exclude these sales altogether. The exclusion of sales such as hair care products or cosmetics is similar to excluding any other type of good that is not pharmaceutical, such as groceries. In a broader multicategory context, different product categories create positive externalities that supermarkets and grocery stores internalize (Thomassen, Smith, Seiler and Schiraldi 2017), which could influence entry patterns. As a consequence of excluding these non-pharmaceutical sales, we may underestimate the amount of entry. However, we do not believe this to be qualitatively important for our results. This is because non-pharmaceutical sales make up only a small fraction of incumbent pharmacies' total sales. In addition, our demand model includes an indicator for the proximity of grocery stores, which captures consumers' preference for one-stop shopping.

Although our entry game may underestimate entry because it does not account for profits from non-pharmaceutical products, there are other reasons why it could overestimate entry. First, entrants in our model are fully myopic, which means they do not anticipate future entrants or try to strategically block competition through their location choices. Second, the model does not account for how new entry affects input costs. Increased demand for labor and retail space could raise wages and rents in input markets, increasing production costs, reducing pharmacy profitability, and deterring further entry. Lastly, our assumption of independent pharmacies may overestimate entry, as individual pharmacies do not consider the business-stealing effects they impose on incumbents. In contrast, if regulations permitted it, horizontal integration through pharmacy chains could internalize these effects. Horizontal integration could also imply decreased fixed costs and economies of scale.

Algorithm 1 Sequential Mopic Entry Algorithm

Initialize a list of potential locations L
Initialize an empty list of store locations S
while there exists a profitable location in L **do**
    For each location $l \in L$, calculate the profit given the existing stores in S
    Find the location $l_{\max}$ with the maximum profit
    if profit at $l_{\max}$ is positive **then**
        Add $l_{\max}$ to S
        For each store $s \in S$, if it is not profitable; remove s from S
    end if
end while
The algorithm terminates when no further profitable locations are found or $\|S\|$ does not change for 10 iterations

6.1 Entry Algorithm

The SME algorithm is shown in Algorithm 1. The algorithm iteratively adds one pharmacy to the market until no new profitable entry locations remain.[34] Each entrant chooses the location with the highest profits at the time of the entry. This is why the algorithm is considered myopic: The entrants do not consider the business-stealing effect caused by and caused to subsequent entrants. If any pharmacies turn unprofitable after new entry, they will exit the market.

In reality, entrants are likely to have some beliefs about future entry. Because entrants do not consider subsequent entry, the algorithm is likely to overestimate the amount of entry. Furthermore, the resulting configuration is not a Nash equilibrium, because some pharmacies might want to change their locations after subsequent entry. Lastly, the existing literature has largely overlooked the algorithm's reliance on fixed costs. In this framework, entry continues until the fixed costs of the last entrant exceed its gross profits. Without fixed costs, other expenses could scale down indefinitely, leading to infinite entry and a lack of convergence. This implies that the choice of fixed costs is crucial in determining the aggregate number of entry. The issue is amplified in our application due to the absence of price competition. However, even with price competition, fixed costs would still serve as a minimum

34. In our implementation of the algorithm, we also make the algorithm terminate if the aggregate number of pharmacies has not increased in 10 consecutive iterations. This avoids the situation where the algorithm gets stuck in a loop of entries and exits.

gross profit requirement for entry. In Appendix Section A.6, we test robustness of our counterfactual results to alternative fixed costs.

For a problem of our size, even the SME algorithm faces computational challenges. To address these, we implement the BSME algorithm shown in Algorithm 2. The BSME algorithm starts with all potential entry locations populated by one pharmacy and then iteratively removes the pharmacy with the largest negative profit until all remaining pharmacies are profitable. This results in a set of locations that can support at least one pharmacy. This is followed by filling these locations with new entrants if some locations can support more than one pharmacy. Because the pharmacies in the entry game are identical apart from their location, we assume that consumers choose randomly between pharmacies in the same location. This assumption means that we do not need to update the choice probabilities during the second stage of the game, as a new entrant does not affect the revenues or profits of neighboring pharmacies. At the end, the resulting configuration of pharmacies may still have locations that are profitable to enter due to consecutive exits in the first stage. To deal with this, we finish the BSME algorithm by running the SME algorithm with the resulting pharmacy allocation. Typically, this last step adds only a handful of new pharmacies before stopping.

The main benefit of the BSME algorithm is that its first step converges to the approximate number of pharmacies in the final configuration much faster than the SME algorithm. This is because the backward step only requires us to check the profits of the existing stores instead of calculating profits for all possible entry locations. This results in a significant reduction in the number of choice probabilities that need to be updated.

In the end, the BSME algorithm produces a configuration that satisfies the same conditions as the SME. However, the configurations that the SME and BSME provide are not necessarily the same. The SME can provide a different configuration depending on the starting configuration, whereas BSME will always provide the same configuration. How the configurations produced by SME or BSME compare to other configurations in the set of all possible configurations is unclear. The BSME is also different from the SME in the sense that it does not produce the order of entry. In some applications where entrants are not identical, the order of entry can matter. In Section 7.2, we compare the performance of BSME and SME.

Algorithm 2 Backward Sequential Myopic Entry Algorithm

Initialize a list of potential locations L
Initialize a list of store locations S so that $S = L$
Initialize choice probabilities $\forall s \in S$
while there exists an unprofitable store in S **do**
    Find the store $s_{\min}$ with the minimum profit
    if profit at $s_{\min}$ is negative **then**
        Remove $s_{\min}$ from S
        For each store $s \in S$, update profits
    end if
end while
Initialize a list of stores $S^* = S$
for $s \in S$ **do**
    while s can accommodate a new entrant **do**
        Add a new entrant s to S^*
        For each store $s \in S^*$, if not profitable; remove s from S^*
    end while
end for
Fill the rest of locations with the SME algorithm.

In the entry game, we do not draw values for $\zeta, \omega_L, \omega_M$, thereby assuming that potential entrants make their entry and exit decisions based on expected profits. This means that our BSME algorithm and the SME algorithm are fully deterministic: Starting from a given network of pharmacies, the algorithms will always converge to the same configurations. An alternative approach would be to allow pharmacies to have different realizations of shocks and condition entry and/or exit on these. Although studying how these assumptions on shocks might affect entry patterns would be interesting, these approaches would introduce new computational challenges, especially in how they interact with the entry algorithms that we use, so we choose not to pursue these approaches.

7 Counterfactual Results

Entry restrictions are often justified by the assumption that they ensure and protect the availability of pharmacy services nationwide. To evaluate this, we simulate a free entry counterfactual pharmacy network in Subsection 7.1 and compare it with

the existing pharmacy network to assess the role of entry regulation in maintaining pharmacy coverage across the country. By keeping the existing price regulation in place, we can isolate and study the specific effects of entry regulation. We analyze the impact of deregulation by calculating changes in consumer welfare, pharmacy revenues, government tax revenue, travel distance to pharmacy, and changes in market concentration measured by HHI. When calculating welfare measures, we convert our travel distance estimates from the (dis)utility of travel time to monetary units following the approach of Einav, Finkelstein and Williams (2016).[35]

In addition to counterfactual results, we also discuss methodological results of the BSME algorithm in Subsection 7.2, and in Appendix Subsection A.6, we show that our counterfactual results presented in Subsection 7.1 are robust to variation in the fixed costs used in the counterfactual.

7.1 Free Entry Counterfactual

Our counterfactual simulation has five main results. First, entry regulation substantially increases the number of pharmacies (1459 pharmacies, 178%). Second, deregulation decreases total welfare (CS+PS+taxes) by €76.5 million (-7%), although most consumers benefit from deregulation. The increase in CS (€67.9 million, 14%) is relatively modest compared to the costs associated with deregulation. Meanwhile, each new pharmacy incurs additional fixed costs, resulting in a significant increase in aggregate industry fixed costs (€162.07 million, 188%) whereas market expansion remains limited (€197.55 million, 8%).

Third, deregulation causes a substantial redistribution of surplus among consumers, pharmacies, and government tax revenue. The government incurs the largest losses due to a sharp reduction in tax revenue (€102.5 million, -24%), but pharmacies also experience a significant decrease in profits (€41.8 million, -28%). The increase in CS is not sufficient to offset these losses.

Fourth, counterfactual pharmacies are smaller in size and this makes pharmacy service production less efficient due to the loss of economies of scale.

Finally, although almost all consumers benefit from deregulation, the benefits are unevenly distributed across different consumer groups and geographical areas,

35. We explain further details of our welfare calculations in Appendix Section A.3.

Table 6: Counterfactual Results

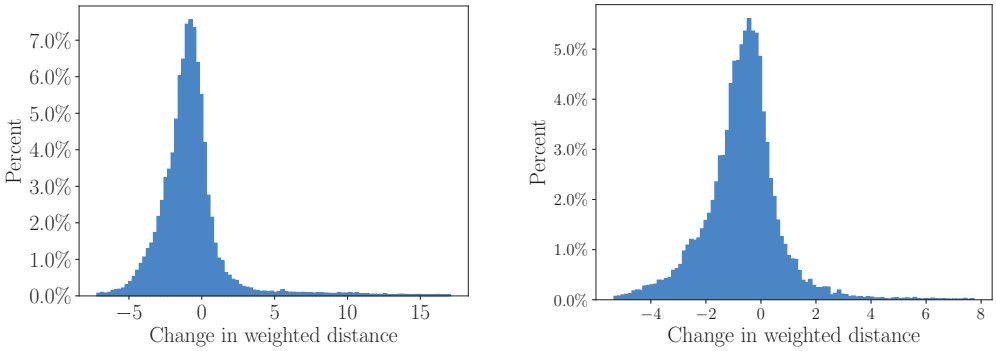
Variable	Absolute	Relative
Panel A: Consumers		
Δ Consumer surplus (CS)	67.94	14%
Sum of negative Δ CS	-1.79	-29%
Average Δ weigh. distance	-0.48	-3%
Panel B: Pharmacies		
Δ Number of pharmacies	1459	178%
Δ Revenue	197.55	8%
Δ Labor costs	57.54	20%
Δ Fixed costs	162.07	188%
Δ Gross profits	120.25	51%
Δ Net profits	-41.73	-28%
Panel C: Government and Total Surplus		
Δ Pharmacy tax	-122.38	-71%
Δ Value-added tax	19.76	8%
Δ Total surplus	-76.41	-7%

Notes: This table shows aggregate changes in the market under free entry counterfactual relative to the current pharmacy network. All monetary values are in thousands of euros. Gross profits are calculated as revenue minus material costs, labor cost and taxes. Net profits are calculated as gross profits minus fixed costs.

with young consumers and urban areas gaining the most. Table 6 Panel A shows how entry deregulation affects consumers. The increase in CS (€67.9 million, 14%) is driven by reduced travel times for consumers who already purchase the inside good and the shift of consumers from the outside good to the inside good. However, focusing only on aggregate CS changes could hide adverse distributional effects of the deregulation policy.[36] With this in mind, the sum of negative CS changes is only around €1.8 million. Moreover, less than 1.5% of the population experience a negative CS change (Appendix Figure A.4). It should therefore be feasible to find not-too-costly remedies to compensate the small fraction of customers who are left worse off. Figure 5 illustrates how the choice probability-weighted distance to

36. Appendix Subsection A.5 presents more detailed heterogeneity analyzes on how different consumer groups were affected by the deregulation policy.

Figure 5: $\Delta E[Distance]$



(a) Cells (b) Population

Notes: The figure on the left plots the distribution of the cell-level changes in expected distance to a pharmacy. The figure on right plots the same changes at the population level. Both figures show the 1–99 percentile range.

pharmacies changes at the cell and consumer level. The core finding is that a large proportion of expected distance changes are in the range of [-6min, 6min].

Table 6 panel B displays how free entry influences pharmacies. Under free entry, we see 1459 more pharmacies than in the regulated system (an increase of 178%). Simultaneously, the sizes of pharmacies decrease due to pharmacies mainly attracting demand from their competitors.[37] We find that aggregate pharmacy revenue increase by €198 million (8%), labor costs by €57.5 million (20%), fixed costs by €162 million (188%), gross profits by €120 million (51%), and net profits or PS decrease by €41.8 million (28%). The 8% increase in aggregate revenue is non-trivial market expansion considering that our RCNL model showed limited substitution between inside and outside goods. Despite this, the revenue increase is still relatively small compared to the large increase in fixed costs and labor costs. The former is driven by the increase in the number of pharmacies, and the latter is caused by both market expansion and the decrease in average revenue per pharmacy, which leads to a loss of economies of scale. Together, the increase in

37. Pharmacy-level characteristics are shown in Appendix A.4.

fixed costs and labor costs leads to a decrease in aggregate industry profits.

An important consideration related to our market expansion result is that standard welfare calculations cannot account for the health effects of increased pharmaceutical spending. On one hand, this spending could be directed towards less effective or redundant treatments. On the other hand, increased spending could result from, for example, distance-sensitive individuals, such as elderly or low-income households, gaining access to nearby pharmacy services. In such cases, the health effects are likely to be positive.

The increase in labor costs stems from two factors: The demand generated by market expansion and the demand driven by reduced labor productivity. To evaluate the loss of labor productivity, we compare ratio of revenues to labor costs between the current regime and the counterfactual. In the current regime, the ratio of predicted revenues to labor costs was 8.5, whereas after deregulation, this ratio drops to 7.7. This reflects a 9.8% decrease in revenue per labor cost. This implies that for every euro of sales, the pharmacy sector spends nearly ten percent more on labor costs after deregulation.

The increased labor costs suggest that pharmacy deregulation leads to significant increase in labor demand for pharmacy professionals. This raises the question whether the supply of labor is sufficient to meet this demand. We argue that the additional workforce required by the pharmacy market is not unrealistically large compared to the existing workforce in the Finnish pharmaceutical industry. Assuming an average salary of €39,000 and a 30% overhead, the increase in labor costs corresponds to an increase of more than 1,100 pharmacists (B.Sc. in Pharmacy). As of 2021, Finland had 10,606 licensed pharmacists (B.Sc. in Pharmacy) under the age of 65, alongside 3,139 licensed pharmacists (M.Sc. in Pharmacy) (National Supervisory Authority for Welfare and Health of Finland 2024). With approximately 4,500 pharmacy professionals currently employed in the pharmacy sector (Kokko, Hyvärinen and Reinikainen 2024), it appears that the labor supply is sufficient to meet the additional demand created by deregulation.[38] However, these calculations do not account for potential wage adjustments caused by increased labor demand. It is likely that wages would rise, suggesting that

38. Figure B.6 in the Online Appendix shows the number of trained pharmacy professionals across the years.

deregulation could shift income from pharmacy owners to employees through higher labor market earnings. This also suggests that our free entry counterfactual likely overestimates entry, as it does not account for the impact of new entrants on prevailing market wages and, consequently, labor costs.

In addition to labor costs, our model does not account for the effects of free entry on the real estate market. Property owners, such as shopping malls, might have incentives to restrict the entry of competing pharmacies to protect or enhance their rental income. Furthermore, the increased demand for retail space could lead to general equilibrium effects, raising costs not only for pharmacies but also for other retailers.

Entry deregulation has the ability to influence government tax revenue through pharmacy tax and VAT. In the free entry counterfactual we keep the existing tax system in place and Table 6 Panel C shows that that aggregate tax revenue collected from the pharmacy industry decreased by around €103 million (-24%). The substantial decrease in tax revenue is explained by the fact that the pharmacy tax is a progressive tax (Appendix Table A.2) based on pharmacies' revenue, and the increase in VAT revenue from market expansion is not enough to balance the decrease from pharmacy tax. Free entry resulted in a decrease in the average size of the pharmacies, which also implied a lower tax burden on pharmacies. A comparison between Table 1 Panel C and Table A.3 Panel C shows that counterfactual pharmacies have, on average, lower per pharmacy revenue than existing pharmacies. The structure of the Finnish tax system explains why aggregate gross profits increased despite the decrease in labor productivity. It also shows that it is the government that is carrying the largest monetary loss from the deregulation policy. In the Finnish context, this suggests that the government should consider reforming the pharmacy tax system alongside policies that deregulate entry to the pharmacy market.

7.2 Methodological Results

Our contribution to the methodological literature on entry algorithms is our BSME algorithm, which converges quickly to a configuration where, at least in our empirical application, almost no one wants to deviate from. Depending on the size of the

problem and the fixed costs, we estimate that our algorithm is at least an order of magnitude faster than the SME algorithm used in the previous literature. For example, in our main specification, the BSME algorithm is more than 40 times faster, taking approximately 90 minutes compared to 3900 minutes for the SME algorithm.[39] The BSME Algorithm, like similar algorithms used in the previous literature, does not necessarily converge to a Nash equilibrium (Seim and Waldfogel 2013; Verboven and Yontcheva 2024). However, we argue that our counterfactual simulation provides a good ballpark estimate of the aggregate number and service coverage of pharmacies in the market under entry deregulation.

8 Conclusions

We study the effects of entry deregulation in the Finnish pharmacy market by i) estimating a spatial model for pharmacy choice, ii) estimating a production function to model variable labor and material costs of operating a pharmacy, and by iii) backing out the upper bound of fixed entry costs from the location choices of existing pharmacies. Free entry results in a significant increase in the number of pharmacies, primarily concentrated in densely populated urban areas. Free entry increases CS for 98% of the population, although the benefits are unevenly distributed. About 2% of consumers experience a decline in welfare due to loss of local services and the need to travel further for pharmacy services. Our results confirm that deregulating a heavily regulated market can be a mixed bag: some consumers gain, but others may be left worse off (Joskow 2005).

Consumers benefit from a larger variety of pharmacies and shorter travel times, but these benefits are outweighed by a significant decrease in industry profits and government tax revenue. The entry of approximately 1400 new pharmacies suggests excessive entry from a welfare perspective, even with more conservative fixed cost estimates. Additionally, the proliferation of smaller pharmacies post-deregulation leads to reduced labor productivity due to foregone economies of scale. In conclusion, we find that the free entry of pharmacies, at least in the absence of other reforms, can lead to a decrease in total welfare compared to the current

39. These simulations were conducted on a server equipped with 128 GB of RAM and an Intel Xeon Gold 6342 processor running at 2.8 GHz

highly restrictive entry and location regime. Although our results suggest that the current pharmacy regulation can work reasonably well from a total welfare perspective, it has potentially undesirable distributional consequences, as it leads to high pharmacy profits and lower CS than the free entry regime. If distributional effects were a concern, a possible remedy could be adjustments to pharmacies' taxation and/or markups.

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A Appendix

This primary appendix contains supplementary materials and is structured as follows. Section A.1 provides further details on the institutional background of the Finnish pharmacy market. Section A.2 outlines our fixed cost estimation strategy. Section A.3 describes the formulas used to calculate CS. Section A.4 presents additional results from our free-entry counterfactual. Section A.5 examines how entry patterns in our main specification vary across different demographic groups. Finally, Section A.6 presents simulation results using alternative fixed cost estimates.

A.1 Institutional Background

Fimea determines the number and locations of pharmacies according to need and pharmaceutical availability. To establish or manage a pharmacy, a pharmacist must be granted a personal pharmacy license by Fimea. A pharmacy license requires a master's degree in pharmacology, the ability to manage a pharmacy, and that the pharmacist has not have been declared bankrupt, appointed a conservator, or convicted of a crime relevant to the operation of a pharmacy. A pharmacist can only hold one license for one main pharmacy at a time but can own up to three additional subsidiary pharmacies that are established at the initiative of Fimea, the pharmacist, or the municipality if Fimea considers it necessary to ensure pharmaceutical availability. As an exception, the University of Helsinki is allowed to own and operate a main pharmacy and up to 16 subsidiary pharmacy branches. Furthermore, the University of Eastern Finland is allowed to operate one pharmacy. Beyond usual pharmacy activities, these pharmacies have a responsibility to carry out activities related to pharmaceutical education and medical research. The manager of a branch pharmacy must be appointed by the pharmacist of the main pharmacy and have a pharmacy degree.[40]

Only pharmacists (with a degree in pharmacology) are allowed to dispense prescription drugs. Wholesalers are required to sell medicines at the same price to

40. For further information on pharmacy license rules, see the Finnish Medicines Act 395/1987 43 b §. The pharmacy privileges for universities are detailed in 42 §, and the subsidiary regulations are in 52 §.

Table A.1: Retail prices for RX and OTC drugs in Finland

Wholesale price (WP)	Retail price (2003)	Retail price (2014)	Retail price (2023)
0–9.25	1.5 × WP + 0.50 €	1.45 × WP	1.42 × WP
9.26–46.25	1.4 × WP + 1.43 €	1.35 × WP + 0.92 €	1.35 × WP + 0.52 €
46.26–100.91	1.3 × WP + 6.05 €	1.25 × WP + 5.54 €	1.24 × WP + 4.92 €
100.92–420.47	1.2 × WP + 16.15 €	1.15 × WP + 15.63 €	1.15 × WP + 13.92 €
over 420.47	1.125 × WP + 47.68 €	1.1 × WP + 36.65 €	1.10 × WP + 33.92 €
over 1 500			1 × WP + 183.92 €

Notes: This table presents the markup regulation for RX and OTC pharmaceuticals in Finland. The second column the retail price formulas applied to RX products between 2003–2013 and for OTC products between 2003–April 2022, after which they apply as maximum pharmacy markups. The third column gives the RX formulas for 2014–2022 and the fourth column presents the current markup formula for RX drugs.

all pharmacies.[41] Retail prices for prescription drugs are determined by a formula based on nationwide wholesale prices, plus a dispensing fee and the VAT. Since 2021, the pricing of OTC drugs is regulated separately from prescription drugs, with a formula based on wholesale price determining the maximum retail price.[42] Reimbursable medicines are reimbursed based on the reference price at a rate of 40%, 65% or 100% depending on the product. The reimbursement system includes an annual minimum copayment of 50 euros and the maximum copayment is capped at roughly 610 euros (for 2024). In generic markets within the reimbursement system, The Pharmaceutical Pricing Board (Hila) establishes reference price groups based on substitutable drugs.[43] In 2021, Kela reimbursed medicines amounting to 1.7 billion euros, representing 47% of total pharmaceutical expenditure and 62% of retail market expenditure for that year (Finnish Medicines Agency and Finnish Social Insurance Institution 2022).

The core principles of the Medicines Act have remained largely unchanged since its introduction in 1987. However, significant modifications have occurred, especially in the areas of generic substitution and pricing. Finland transitioned

41. For the dispensing rules, see Fimea order 2/2016 Sectio 4.2. Price discrimination at the wholesale-level is forbidden by the Finnish Medicines Act 37 a §.

42. Pharmacy prices are governed by the Finnish Medicines Act 58 §, whereas the markups are set by a government degree. The markups during our data sample are given in Degree 713/2013, while the OTC rules were changed in Degree 193/2022.

43. The reimbursement rates are set in Section 5 of the Finnish Health Insurance Act 1224/2004. The reference price system has been in place since April 1st, 2009. It is governed by Section 6 18–24 §.

Table A.2: Pharmacy Tax Rates

Revenue Range (€)	Base Tax at Lower Bound (€)	Tax Percentage for Excess Revenue (%)
871,393–1,016,139	0	6.10
1,016,139–1,306,607	8,830	7.15
1,306,607–1,596,749	29,598	8.15
1,596,749–2,033,572	53,245	9.20
2,033,572–2,613,212	93,432	9.70
2,613,212–3,194,464	149,657	10.20
3,194,464–3,775,394	208,945	10.45
3,775,394–4,792,503	269,652	10.70
4,792,503–6,243,857	378,483	10.95
Over 6,243,857	537,406	11.20

Notes: This table presents the pharmacy tax rates in Finland. The tax rates are based on the pharmacy revenues.

from voluntary to mandatory general substitution, which requires pharmacy staff to dispense the cheapest available substitute, in 2003 in an effort to reduce pharmaceutical expenditure. The sale of nicotine products in places other than pharmacies has been allowed since 2006.[44] Until 2010, a pharmacist had to be a citizen of a country in the European Economic Area (EEA) to own a pharmacy in Finland. The same amendment introduced regulation of online pharmacies, allowing licensed pharmacists to open an online pharmacy after notifying Fimea.[45] In 2016 the pharmacy fee was replaced by the pharmacy tax, which also transferred responsibility for the payment from Fimea to the Finnish tax authority.[46] We present the pharmacy tax rates in Table A.2. The pharmacy tax in Finland is based on pharmacist's total revenue from all locations (the main pharmacy and its subsidiaries). Although the highest tax brackets in Table A.2 exceed the current markups in Table A.1, the revenues from pharmaceutical sales exceeding the €1,683.92 retail price level are not included in the revenues included in the calculation of the pharmacy tax.

44. Generic substitution was adopted in an amendment to the Finnish Medicines Act 80/2003 57 b §. The sale of nicotine products was liberalized in 22/2006 54 a–54 e §.

45. See Finnish Medicines Act 1112/2010 43 § and 52 b §.

46. Although the tax rates have been adjusted to benefit small and branch pharmacies, the current rates have remained constant since 2013. For further reference, see Amendment 977/2013 2 a §.

The current tax system is revenue-based, unlike standard business taxes that are based on gross profits. We maintain the same tax system in place in our counterfactual simulation. Consider a median pharmacy with a taxable revenue of €3,480,000 and a profit net of materials and labor of €490,000. According to the tax table, this revenue falls in the range of €3,194,464 to €3,775,394. The base tax at the lower bound of this range is €208,945, and the tax percentage for the excess revenue over the lower bound is 10.45%. To calculate the total tax, first determine the excess revenue over the lower bound: Excess Revenue = €3,480,000 - €3,194,464 = €285,536. Then, calculate Tax on Excess Revenue = €285,536 × 0.1045 = €29,838.51. Finally, add the base tax at the lower bound: Total Tax = €208,945 + €29,838.51 = €238,783.51. For comparison, the standard corporate tax of 20% would result in a tax of €94,722.40.

A.2 Fixed Cost Algorithm

We present our fixed cost estimation algorithm in Algorithm 3. This algorithm is based on Eizenberg (2014) and proceeds in three phases steps. In the first phase (Algorithm 3 step 1), joint probability distribution of demand, labor and material costs shocks is estimated. This requires that prior this step the demand system and production function have been estimated. In the second phase (Algorithm 3 steps 2-6), demand and cost shocks are drawn from the joint distribution and for each draw gross profits are calculated. This allows to compute the upper bound fixed cost for each draw of the shocks. In the last phase (Algorithm 3 step 6), the fixed cost upper bound estimate is obtained by averaging the gross profits over the Y draws.

Algorithm 3 Fixed Cost Estimation Algorithm

1: Use realized demand, labor and material shocks $\hat{\zeta}$, $\hat{\omega_L}$, and $\hat{\omega_M}$ to estimate joint probability distribution of the shocks $f_{\zeta,\omega_L,\omega_M}$
2: Take Y draws from the joint distribution $(\zeta_y, \omega_{Ly}, \omega_{My}) \sim f_{\zeta,\omega_L,\omega_M}$
3: **for** each pharmacy s and each draw y **do**
4: Calculate gross profits:

$$\Pi_{sy} = \overbrace{\hat{R}_s \times \exp(\zeta_y)}^{\text{Revenue}} - \overbrace{\frac{1}{B+\omega_{My}} \times \hat{R}_s \times \exp(\zeta_y)}^{\text{Material costs}}$$
$$- \underbrace{(\frac{\hat{R}_s \times \exp(\zeta_y)}{\exp(A)})^{\frac{1}{\kappa}} \times \exp(-\frac{\omega_{Ly}}{\kappa})}_{\text{Labor costs}} - \underbrace{T(\hat{R}_s \times \exp(\zeta_y))}_{\text{Taxes}}$$

5: Compute the upper bound fixed cost:

$$\bar{F}_{sy} = \Pi_{sy}$$

6: **end for**
7: Estimate the fixed cost upper bound by taking the average over Y draws:

$$\bar{F}_s = \frac{1}{Y} \sum_{y=1}^{Y} \bar{F}_{sy}$$

A.3 Welfare Calculations

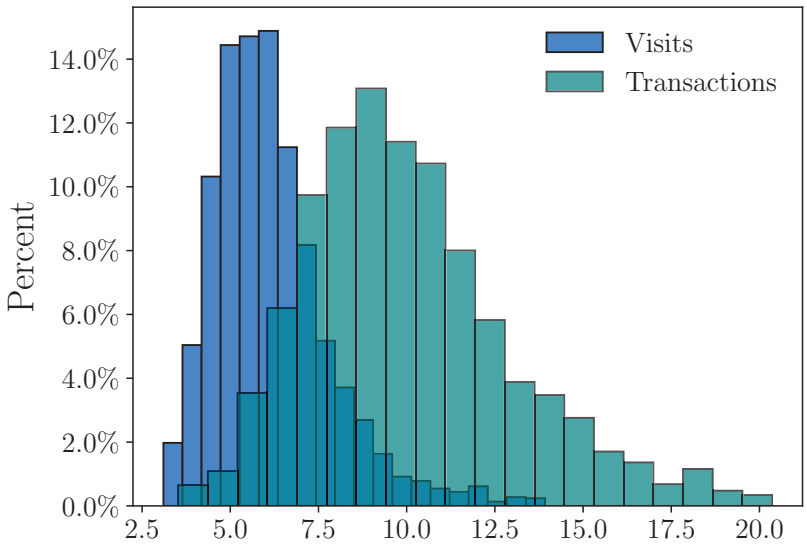
Our welfare analyses help us to understand how different counterfactual scenarios influence the Finnish pharmacy market. The main interest is in what happens to consumer welfare when the surrounding pharmacy network changes. However, a challenge to surplus calculations is that due to uniform pricing in the Finnish pharmacy sector, our pharmacy choice model does not include prices that we could use to calculate consumer surpluses in monetary terms. We overcome this by focusing on the changes in consumers' travel distance and converting these to monetary terms with an outside estimate of travel cost t_{dt}. In addition, we assume that the marginal utility of the distance traveled is independent of the income of the consumer. This assumption means that our welfare analyses do not consider income effects. The rationale for the assumption is the regulatory and reimbursement system that makes consumer choices less dependent on income. A change in CS for post code t can be calculated using the following formula:

$$\Delta E\left(\mathrm{CS}_t\right) = \int \frac{t_{dt}}{\beta_i^{dist}} \left[I_i^1 - I_i^0\right] d\beta_i, \tag{20}$$

where β_{dist} represents the estimated distance parameter from the demand model and the I terms represent the log-sum from equation (8) with the superscript 0 denoting the baseline model and superscript 1 the counterfactual scenario (Train 2009). The term $\Delta E(CS_t)$ should be interpreted as the average consumer surplus for sub-population who have the same utility as individual i. This idea can be used to calculate surplus changes for consumers living in a certain geographic area (Hackmann 2019) or with respect to certain consumer demographics (Bento, Goulder, Jacobsen and Von Haefen 2009; Conlon and Rao 2023). The total surplus in the general population is then calculated as the weighted sum of equation (20) where the weights represent the number of consumers who share the same representative utility (Train 2009).

In equation (20) we add term t_{dt} to the numerator before the square brackets, because this allows us to monetize consumer utility in a scenario where demand specification does not include a price coefficient (Verboven and Yontcheva 2024). Previous literature contains two alternative approaches for obtaining the parameter t_{dt} in equation (20). The first method, as used by Verboven and Yontcheva (2024),

Figure A.1: Pharmacy Visits and Transactions



Notes: The figure plots the distributions of pharmacy visits and transactions accross postal code areas.

involves using travel cost estimates from previous studies.[47] The second way to obtain a travel cost estimate is to calculate the income a consumer loses if they need to travel to a pharmacy instead of using that travel time for work. This approach, described by Einav, Finkelstein and Williams (2016), is simple because it only requires information on the travel time to the pharmacy and the consumer's income.[48] It is also our method for calculating travel costs. We calculate travel cost (t_{dt}) using the following formula:

$$t_{dt} = 2 \times \text{average hourly wage} \times N_{trips} \tag{21}$$

Equation (21) provides travel cost estimate for each cell t. We base our travel costs calculations on using auxiliary data sources, as we are not aware of any

47. Ramjerdi and Lindqvist Dillén (2007) and Gowrisankaran, Nevo and Town (2015, 2015) provide direct estimates that we could use in our application.

48. Einav, Finkelstein and Williams (2016) calculate travel costs for radiology services as average wage × trips to radiology facility × 2

studies that estimate health service travel costs in Finland. We parametrize equation (21) by using the average hourly wage in Finland and the average number of pharmacy visits by each postal code area. Equation (21) contains multiplication with number two as the consumer needs to drive home from the pharmacy. We plot the distribution of pharmacy visits in Figure A.1 together with the transactions. The figures demonstrates that consumers typically make several purchases per visit.

A.4 Additional Counterfactual Simulation Results

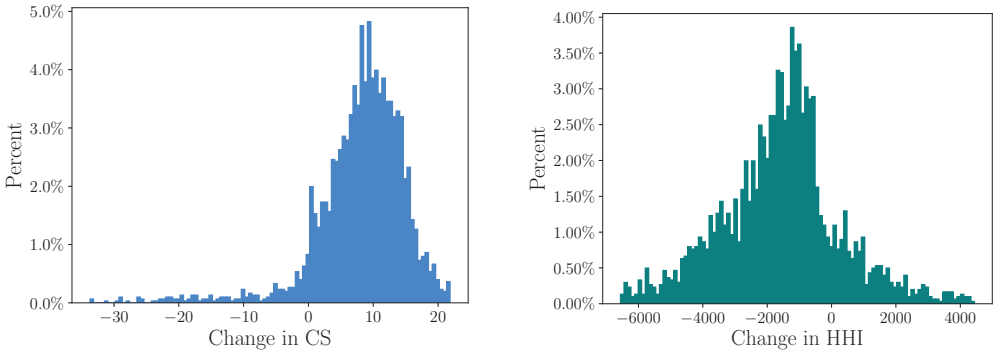
In this Subsection we provide additional results on how free entry affects market concentration and CS changes at the cell and at the population level. These analyses are presented in Figure A.2 and Figure A.3 displays the pharmacy network configuration under regulated and free entry.

Figure A.2 plots the cell-level distribution for changes in CS (Figure A.2a) and HHI (Figure A.2b). There are two important insights. First, CS is positive for almost all cells, but the distribution's left tail is very long, and this indicates that the policy benefits are very unequally distributed. Another observation is that market concentration increases for a substantial share of cells (around 13%), but these cells have low population density—Appendix Figure A.4 shows that only around 1.5% of the Finnish population face an increase in market concentration. At the same time Figure A.4 shows that for 1% of the population, welfare decreases despite a reduction in market concentration.[49] This interesting pattern occurs when consumers lose access to local services and must travel to more distant areas with higher competition. Our findings demonstrate that, in some edge cases, improvements in market concentration metrics can counterintuitively lead to welfare losses. In Subsection A.5 we use descriptive regressions to show how CS, HHI, and negative CS changes are associated with consumer demographics and geographical areas.

Finally, Figures A.3a and A.3b show the counterfactual and the existing pharmacy network side by side. When comparing these figures, we see that urban areas tend to get more pharmacies under deregulation, but this increased entry to urban

49. Appendix Figure A.4 cross tabulates CS and HHI changes on the basis of the CS and HHI sign changes. The majority of CS increases coincide with HHI decreases, and vice versa (96% of consumers).

Figure A.2: Δ CS and Δ HHI Distributions



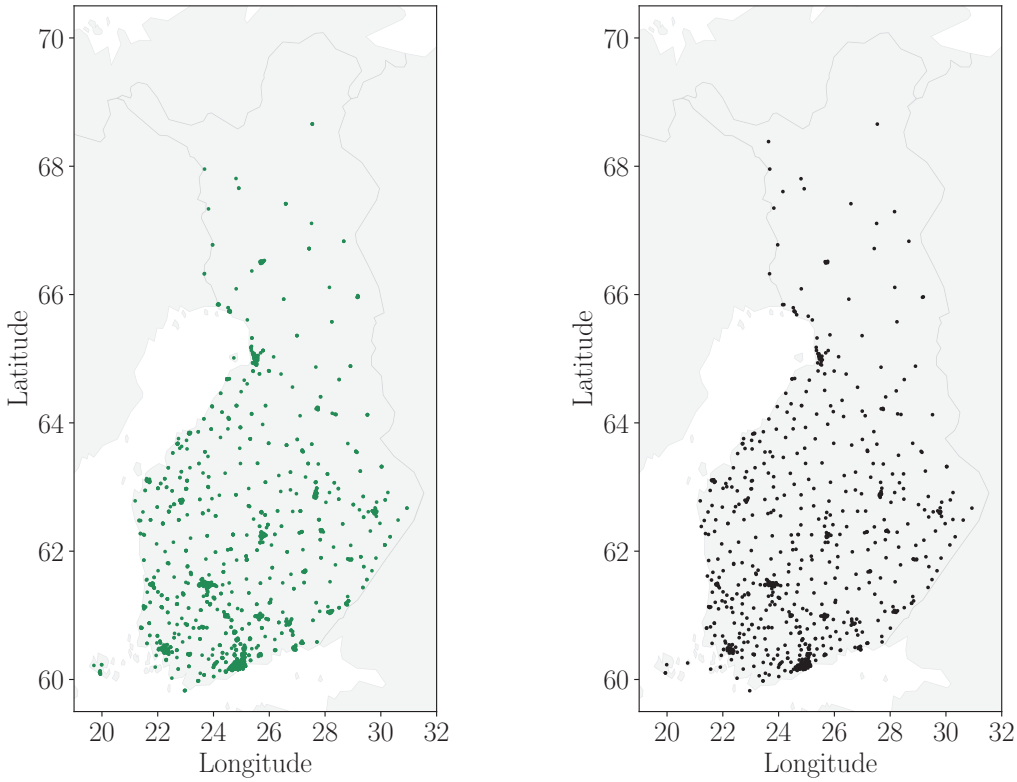
(a) Δ CS (b) Δ HHI

Notes: The figure on the left plots the distribution of the cell-level changes in CS per capita. The figure on the right plots the changes in HHI. Both figures show the 1–99 percentile range.

areas does not remove rural pharmacies from the network. The most significant change in the pharmacy network occurs in Northern Finland, where the upper part of the country is left without pharmacies. Online Appendix Figure B.5b displays the counterfactual pharmacy network for the Helsinki capital region.

Table A.3 presents the descriptive statistics for the free entry counterfactual scenario. In Panel A, we show the statistics at the representative consumer (cell) level for changes in HHI concentration, CS and two different distance measures and Panel B represents the same statistics for the actual population that lives in these cells. The first distance measure is the weighted distance, where we weight the distance to pharmacies with their consumer-level choice probabilities. The minimum distance simply gives the minimum distance in the choice set. Most importantly, the results in Table A.3 Panel A show that, on average, consumer welfare increases through increased competition, which is denoted by the substantial average decrease in HHI. Importantly, in most areas, consumer welfare increases as shown by the positive 10th percentile threshold. Comparisons between CS distribution 10th, 50th and 90th percentile in Table A.3 Panels A and B show that consumer surplus increases are mainly positive, but unevenly distributed in the

Figure A.3: Counterfactual Pharmacy Network



(a) Counterfactual Network

(b) Existing Pharmacy Network

Notes: The figure on the left plots the post entry game pharmacy network. The figure on the right shows old pharmacy network.

population. We present the empirical distributions of the cell-level HHI and CS changes in main text Figure A.2.

Table A.3 Panel C displays descriptive statistics for pharmacies that enter the Finnish market in our counterfactual. Due to free entry, the number of pharmacies increases substantially from the regulated baseline scenario. Counterfactual pharmacies are on average smaller and less profitable than pharmacies in the regulated scenario (compare Table 1 Panel C and Table A.3 Panel C). This change is an expected result, because business stealing between pharmacies significantly decreases

Table A.3: Entry Descriptive Statistics

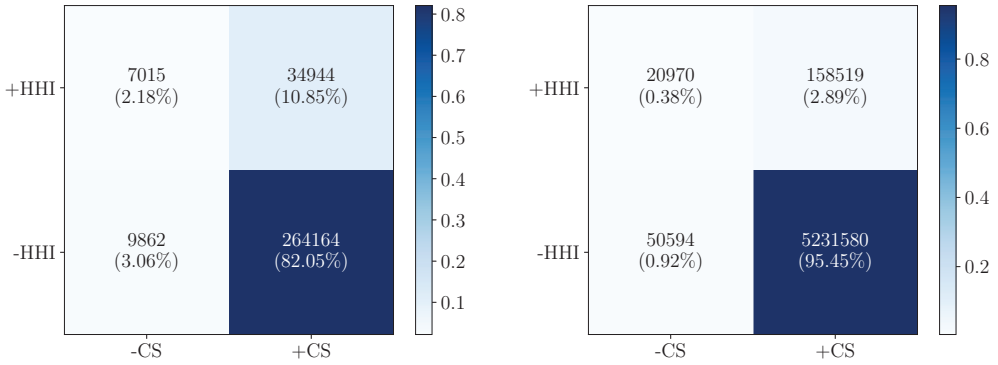
Variable	Mean	Std. Dev.	P10	P50	P90	N
Panel A: Cell characteristics						
Δ HHI	-1914.91	2186.36	-4656.22	-1774.99	442.45	315985
Δ CS	211.04	840.80	3.62	27.59	388.43	321950
Weigh. distance	16.04	12.78	6.56	14.45	25.93	315980
Min distance	12.99	13.94	3.12	10.86	24.40	315985
Panel B: Consumer characteristics						
Δ HHI	-1814.04	1594.27	-4079.24	-1414.29	-465.57	5461663
Δ CS	12.40	6.50	7.57	13.04	17.46	5480966
Weigh. distance	9.70	6.53	4.45	8.88	15.42	5461654
Min distance	4.97	6.92	1.11	3.16	11.22	5461663
Panel C: Pharmacy characteristics						
Revenue	1183.56	208.68	945.13	1150.51	1479.06	2276
Labor costs	154.23	20.26	137.28	146.12	184.84	2276
Pharmacy tax	21.48	15.51	4.50	18.44	43.65	2276
Net profit	46.03	23.61	11.85	47.34	76.55	2276

Notes: This table presents descriptive statistics of the free entry counterfactual. The first panel consists of cell-level measures, second panel of consumer-level measures, and third panel of pharmacies. The 2276 pharmacies in the market are located in 2191 unique locations. All variables are in absolute values.

the revenue per pharmacy whereas the market expansion effects are modest. At the same time the average labor input decreases. Labor costs do not vary between counterfactual pharmacies as much as costs vary in the regulated scenario.

Figure A.4 tabulates cell and population specific CS and HHI changes. This tabulation clearly shows that, after the removal of entry restrictions, most cells and a majority of the Finnish population experience an improvement in consumer CS. Figure A.4a shows that 82% of cells are such that market concentration decreases and consumer surplus increases and only around 2% of the cells are such that market concentration increases and consumer surplus decreases. Welfare decreases only for 5% of the cells in comparison to the regulated scenario. The results are

Figure A.4: HHI and CS combinations



(a) Cells (b) Population

Notes: The figure on the left plots the combinations for HHI and CS pairs between cells. The figure on the right scales these by population. The population counts differ slightly from Table A.5 because of missing HHI values due to loss of service.

qualitative the same when the effects of the deregulation policy on the whole population are studied in Figure A.4b. Now it is important to observe that the magnitude of adverse effects shrinks, because in reality many people can live in the same cell. If cells facing adverse effects are small in comparison to cells that benefit from the policy, then this should reduce the number of people who do not gain from the policy. Only around 1.5% of the Finnish population lose in terms of consumer welfare. It is worthwhile to mention that almost 95.5% consumers face increases in consumer surplus and a reduction in market concentration.

A.5 Heterogeneity Analysis

Results included in the main text showed that allowing free entry into the Finnish pharmacy market leads to a large majority of consumers experiencing an increase in welfare, with a modest average increase in aggregate CS. In this subsection, we examine how the benefits of free entry are distributed across different demographic groups and geographical areas. Specifically, we investigate the incidence of reform benefits to determine whether certain demographic groups or geographical locations

systematically gained more from the policy, or if the gains from the deregulation were evenly distributed across consumers and regions. We aggregate our data to the postal code level because most of the demographic information is censored at the cell-level. We quantify the changes by estimating a linear regression model presented in equation (22):

$$\Delta\bar{y}_p = \bar{X}_p\beta + \bar{Z}_p\gamma + \bar{\varepsilon}_z. \tag{22}$$

We have three outcome variables ($\Delta\bar{y}_p$) for the distributional impact of the reform: Percentage change in CS, percentage change in HHI, and an indicator for a negative change in CS. We regress these outcome measures on mean demographics $\bar{X}$ and regional characteristics $\bar{Z}$. The vector of demographic characteristics ($\bar{X}$) contains log average income, log average age, share of pensioners, share of unemployed, and the share of population with only comprehensive education. For the geographic characteristic ($\bar{Z}$) we include a degree of urbanization that is divided into "Urban", "Suburban", and "Rural". Our base group are rural areas, and the two dummies distinguish between cities ("Urban") and neighborhoods surrounding cities ("Suburban").

The first column of Table A.4 shows the results for the change in CS, the second column for the change in HHI, and the last column for characteristics associated with a decrease in CS. The results in the first column (change in CS) are consistent with our earlier observation that rural areas with an older population and more pensioners tend to benefit less from free entry. Regions characterized by higher unemployment, lower educational attainment, and suburban locations exhibit a more pronounced increase in CS as a result of deregulation. However, only age and the degree of urbanization yield statistically significant coefficients.

Column 2 in Table A.4 presents the regression results for changes in the aggregated HHI index. Higher average income, the share of pensioners and unemployed, and the suburbia indicator are all associated with a decrease in the HHI. In contrast, areas with older and less educated populations, as well as suburban areas, see an increase in HHI. Statistically significant coefficients are found for income, age, the share of pensioners, education, and the suburban dummy. The results for market concentration closely mirror the results for the change in CS, as the changes in

Table A.4: Heterogeneity Analysis

Dependent Variable:	% Δ CS	% Δ HHI	Δ CS < 0
Model:	(1)	(2)	(3)
Dependent Variable Mean	.1125	-.4101	.0758
	(.0036)	(.0077)	(.0048)
Independent Variables			
Log Average income	.0404	-.245***	-.0286
	(.0327)	(.0657)	(.0458)
Log Average age	-.0032*	.0256***	.007***
	(.0017)	(.0035)	(.0024)
% pensioners	-.073	-.3383	.0594
	(.1037)	(.2089)	(.1455)
% unemployed	.0445	-1.244***	-.355
	(.1803)	(.3647)	(.2528)
% comprehensive education only	.0832	.3333**	.2391**
	(.0796)	(.1601)	(.1116)
Suburban	.0278***	-.0253	-.0163
	(.0095)	(.019)	(.0133)
Rural	-.0253***	.143***	.0186
	(.0087)	(.0175)	(.0122)
Constant	-.1388	.911	-.0182
	(.3326)	(.6688)	(.4665)
Observations	2910	2897	2910
R^2	.0347	.2235	.0639

Notes: Municipality groups follow Statistics Finland definitions: Urban: Cities, Suburban: Densily populated municipalities, Rural: Rural municipalities. Clustered standards errors in parentheses; * p< 0.1, ** p< 0.05, *** p< 0.01.

market structure is the main driver behind the change in CS.

Our analysis suggests that changes in CS and HHI vary with demographic and geographic characteristics. In Table A.4, Column 3, we further examine how these characteristics are associated with a decrease in CS. For this, we use an indicator to denote whether the postal code area faced a decrease in CS or not. The results show that the age of the population, the share of pensioners, the share of consumers with only comprehensive education, and suburban areas face a decrease in CS

relatively more often. The opposite applies to areas with higher average income, higher unemployment, and areas that are considered urban.

Although most coefficients in Table A.4 are not statistically significant, the results suggest that rural areas and areas with higher proportions of pensioners benefit less from entry deregulation than consumers living in urban areas.

A.6 Free Entry Counterfactual with Alternative Fixed Costs

This analysis revisits our free entry counterfactual by changing the fixed costs used in the analysis. Analyses with increased fixed costs intuitively mean that we artificially raise the minimum profit requirement for operating a pharmacy both in rural and urban areas. We use this analysis to understand how robust our headline results are to changes in the fixed costs. We adjust our counterfactuals with fixed costs set to the 25th quantile and the median of the distribution of estimated fixed cost upper bounds and we calculate separate costs for urban and rural regions.

Table A.5 presents the main results for different fixed costs specifications. The first column presents the main results discussed in section 7 as a benchmark, whereas the second and third columns present results for the alternative fixed costs. Even with unrealistically high fixed cost, the change in total surplus (TS) remains negative, but the negative surplus change is much smaller than in the main results (Table A.5 column 1). Changes in TS are mainly explained by decreased aggregate fixed and labor costs in addition to increased pharmacy tax revenue.

Increasing fixed costs decreases aggregate CS in comparison to the main results, but the aggregate CS does not decrease linearly. With fixed costs set in the 25th Quantile, the change in aggregate CS is 6 pp. smaller than in the main results, but with median fixed costs, the change in CS is only 9 pp. smaller. It is worthwhile to note that even with Quantile 50 fixed costs (Table A.5 column 3) the number of pharmacies increase by 136 pharmacies (17%). The sum of negative CS changes increases in absolute value. The sum of negative CS either doubles (Quantile 25) or almost quadruples (Quantile 50). This means that even with unrealistically high fixed costs, the negative CS changes are in per capita terms quite modest and it should be relatively easy to find ways to compensate individuals who are hurt by the reform.

Table A.5: Counterfactual Results With Different Fixed Costs

Variable	**Fixed Costs Quantile 0**	**Fixed Costs Quantile 25**	**Fixed Costs Quantile 50**
	Panel A: Consumers		
Δ Consumer surplus (CS)	67.94	39.23	25.45
	(14%)	(8%)	(5%)
Sum of negative Δ CS	-1.79	-3.72	-7.01
	(-29%)	(-25%)	(-19%)
Average Δ weigh. distance	-0.48	-0.06	0.49
	(-3%)	(-0%)	(3%)
	Panel B: Pharmacies		
Δ Number of pharmacies	1459	429	136
	(178%)	(52%)	(17%)
Δ Revenue	197.55	92.59	35.24
	(8%)	(4%)	(1%)
Δ Labor costs	57.54	22.34	10.48
	(20%)	(8%)	(4%)
Δ Fixed costs	162.07	90.26	35.92
	(188%)	(55%)	(18%)
Δ Gross profits	120.25	50.61	21.74
	(51%)	(22%)	(9%)
Δ Net profits	-41.73	-39.49	-13.99
	(-28%)	(-56%)	(-35%)
	Panel C: Government and Total Surplus		
Δ Pharmacy tax	-122.38	-46.98	-22.34
	(-71%)	(-27%)	(-13%)
Δ Value-added tax	19.76	9.26	3.52
	(8%)	(4%)	(1%)
Δ Total surplus	-76.41	-37.98	-7.35
	(-7%)	(-4%)	(-1%)

Notes: This table shows aggregate changes in the market under free entry counterfactual relative to the current pharmacy network. The columns represent different specifications for fixed costs. All monetary values are in thousands of euros. Gross profits are calculated as revenue minus material costs, labor cost and taxes. Net profits are calculated as gross profits minus fixed costs.

Table A.5 Panel B displays changes in pharmacy revenue, labor costs, fixed costs, and gross and net profits for the different fixed cost specifications. With Quantile 25 fixed costs, pharmacy revenue is 4 pp. smaller than in baseline results, but for median fixed costs, the difference is only 1 pp. . At the same time, labor costs are 12 pp. (Quantile 25) or 16 pp. (Quantile 50) smaller than in the baseline scenario. At the same time net pharmacy profits remain smaller than in the regulated scenario but net profits are larger than in the free entry counterfactual. Sum of net profits changes non-linearly between different columns in Table A.5 because same fixed costs are applied to the status quo situation and to the counterfactual scenario.

The change in pharmacy and value added taxes is reported in Table A.5 Panel C. Tax revenue from pharmacy taxes is smaller than it was under entry regulation because tax is revenue based, but with Quantile 25 or Quantile 50 fixed costs tax revenue from pharmacy tax increases in comparison to free entry counterfactual (Table A.5 column 1 vs columns 2 and 3). The opposite happens with value added tax, because aggregate pharmacy market sligthly expands in counterfactual scenario. Market expansion mechanically leads to value added tax revenue increasing in comparison to regulated scenario.

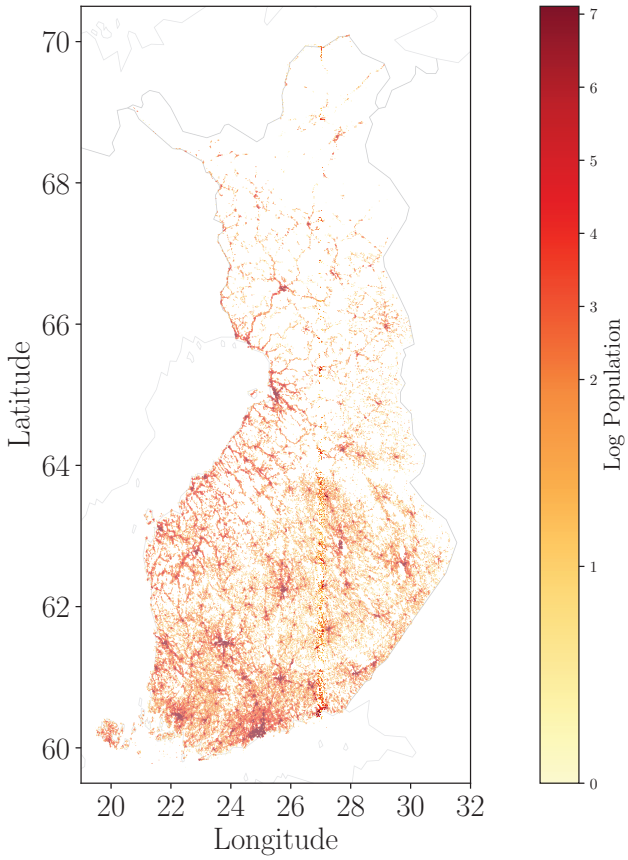
B Online Appendix

This secondary appendix contains supplementary materials and is structured as follows. Section B.1 provides several maps of descriptive statistics and counterfactual simulation results. Section B.2 offers an overview of EU regulatory frameworks across member states. Section B.3 describes the datasets used in the analysis and their sources. Section B.4 explains the methodology for calculating travel times between locations. Section B.5 presents time series of the labor supply of relevant pharmacy professionals. Section B.6 outlines the derivations for the analytical gradients used in the optimization procedure. Finally, Sections B.7 and B.8 include the mathematical expressions and results for computing elasticities and diversion ratios from the demand model.

B.1 Additional Maps

Descriptive Statistics. We present the map of Finland with log population densities in Figure B.1. Finland's population is highly unevenly distributed, with the majority concentrated in the southern and southwestern regions. In contrast, much of Finland's northern and eastern regions are sparsely populated.

Figure B.1: Finland Population Map

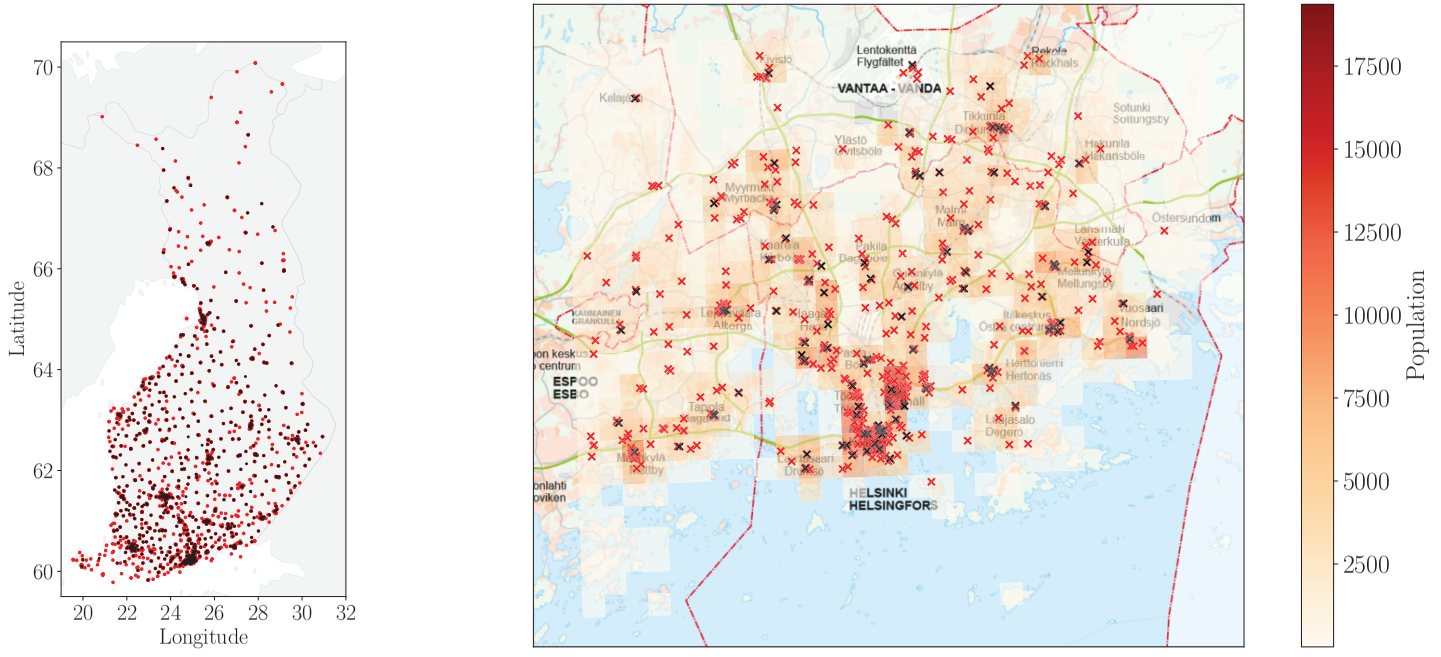


Potential Entry Locations. The computationally most challenging part in the SME and BSME algorithms is related to the size of the set of potential entry locations L. With our 250m×250m sized map, the number of potential entry locations is in the hundreds of thousands, so iterating over the entire set is slow. Faced with similar problems, Verboven and Yontcheva (2024) restrict L to locations close to post offices. We take a similar approach and restrict entry to all locations next to a grocery store in Finland, which yields roughly 4000 potential entry locations. The choice to use grocery stores, supermarkets and key retail centers as potential entry location comes from the Finnish policy discussion where significant policy interest is on should groceries be allowed to sell pharmaceuticals as pharmacies do. We plot the possible entry locations in Figure B.2.

For several reasons, we argue that this is a rather conservative approach. First, we allow the entry of multiple pharmacies in the same location, which means that the number of entrants can exceed the number of locations. Second, the deregulation of the pharmacy markets in Norway and Sweden gives us a good benchmark for the number of pharmacies in equilibrium. In Norway, the number of pharmacies increased from 395 pharmacies in 2000 to 1045 pharmacies in 2023 (Rudholm 2008; Norwegian Pharmacy Association 2024). In Sweden, the number of pharmacies increased from 929 to 1407 between the years 2010–2022 following entry deregulation in 2009 (Swedish Pharmacy Association 2023). Furthermore, OECD (2023) reports an average of 28 pharmacies per 100,000 inhabitants in OECD member countries in 2021. For Finland, below the mean with 15 pharmacies per 100,000 inhabitants per pharmacy, an average rate or a maximum rate of 47 would correspond to 1600–2600 pharmacies.[50] Thus, we expect that our restriction on L has limited influence on our results, but it significantly reduces computational time.

50. In 2021, Spain had approximately 47 pharmacies per 100,000 people. Greece had the highest rate of 97, more than double that of Spain.

Figure B.2: Potential Entry Locations



(a) Whole Finland

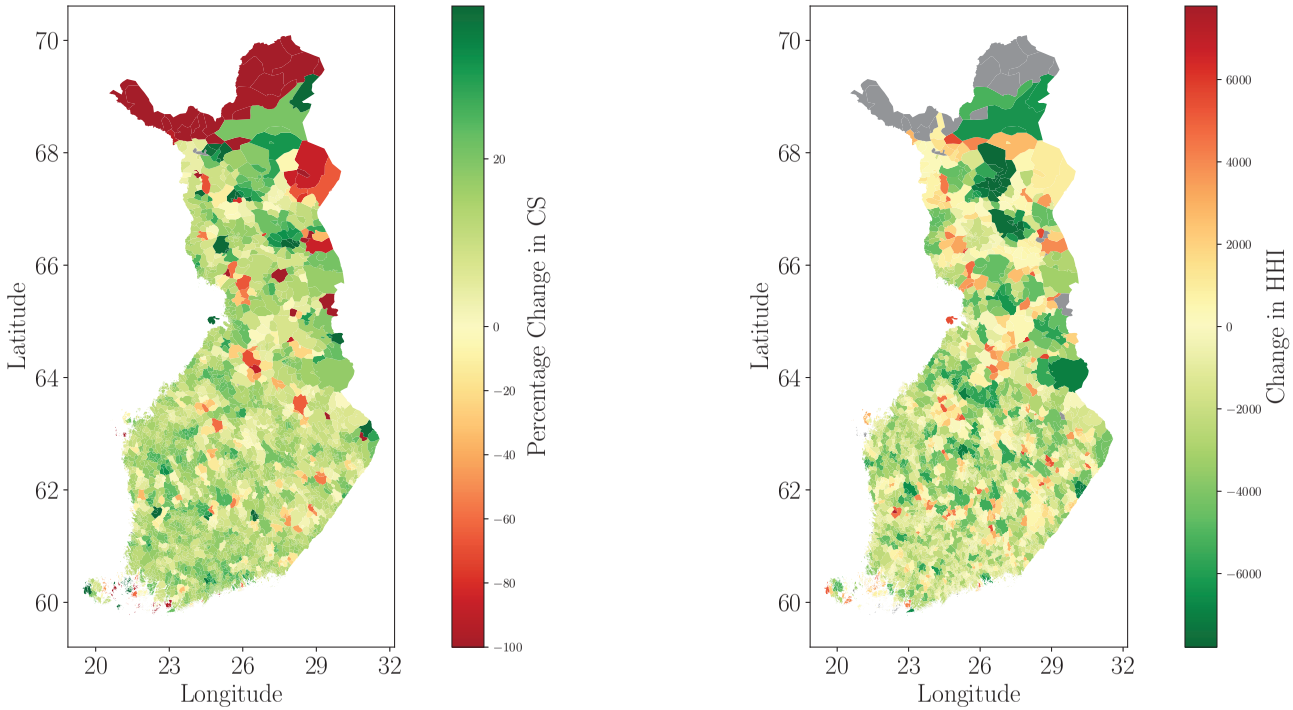
(b) Helsinki

Notes: The figure on the left plots the entry locations and pharmacy locations. The figure on the right shows the same locations in Helsinki. Sources for the maps: Fimea (2021), Nominatim and OpenStreetMap contributors (2024), Statistics Finland (2023), Helsinki City Survey Services, Cities of Espoo, Vantaa, and Kauniainen (2022) and EuroGeographics (2024).

Free Entry Counterfactual Results in Spatial Form. We present the changes in CS and HHI below, along with the HHI classifications. Finally, we provide the map of our counterfactual simulation (main specification).

In Figure B.3, we aggregate our cell-level results to the postal code level and plot maps showing how CS and HHI illustrate changes in postal code-specific consumer welfare and HHI across Finland. These maps show that adverse CS effects mainly come from Northern and Northeast Finland, and because these areas are sparsely populated, the direct population impact remains modest. The increases in market concentration are distributed more evenly across Finland than decreases in CS.

Figure B.3: Postal Code-level Changes in CS and HHI



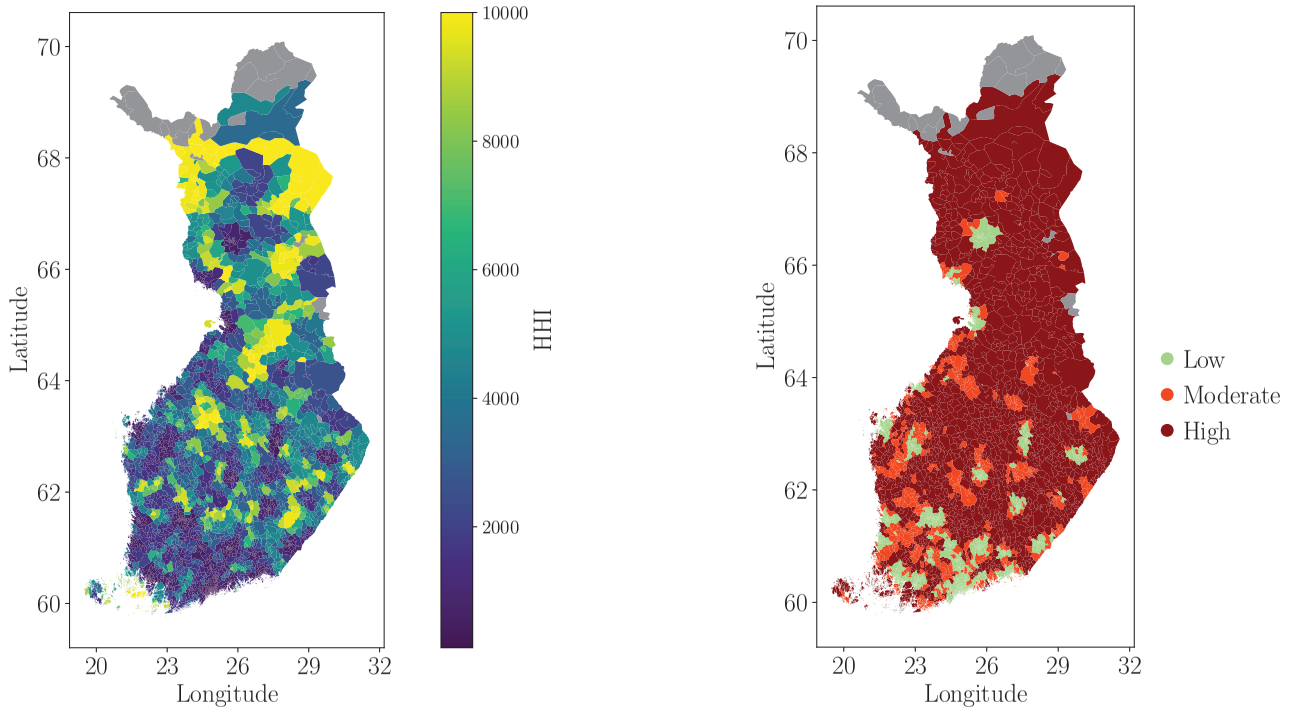
(a) Change in CS

(b) Change in HHI

Notes: The figure on the left shows the change in CS for all postal code areas in Finland. The figure on the right shows the change in HHI. Gray areas denote loss of pharmacy access. Source: Statistics Finland (2021).

Figure B.4 illustrates the market concentration in the counterfactual scenario. Figure B.4a displays post code-level HHI and Figure B.4b displays HHI split into categories Low (green), Moderate (orange) and High (Red). Two important facts can be seen from HHI figures. Most of the heavily concentrated (HHI close to 10,000) postal code areas are located in Northern Finland which is inline with the CS changes presented in Figure B.3a. Secondly, the use of HHI thresholds reveals that in the counterfactual scenario only large cities and densely populated areas are the locations where market concentration measured in HHI is low. The usual caveats and challenges related to HHI use must be taken into consideration when Figure B.4 is interpreted through the lens of market concentration.

Figure B.4: HHI Entry Game Maps



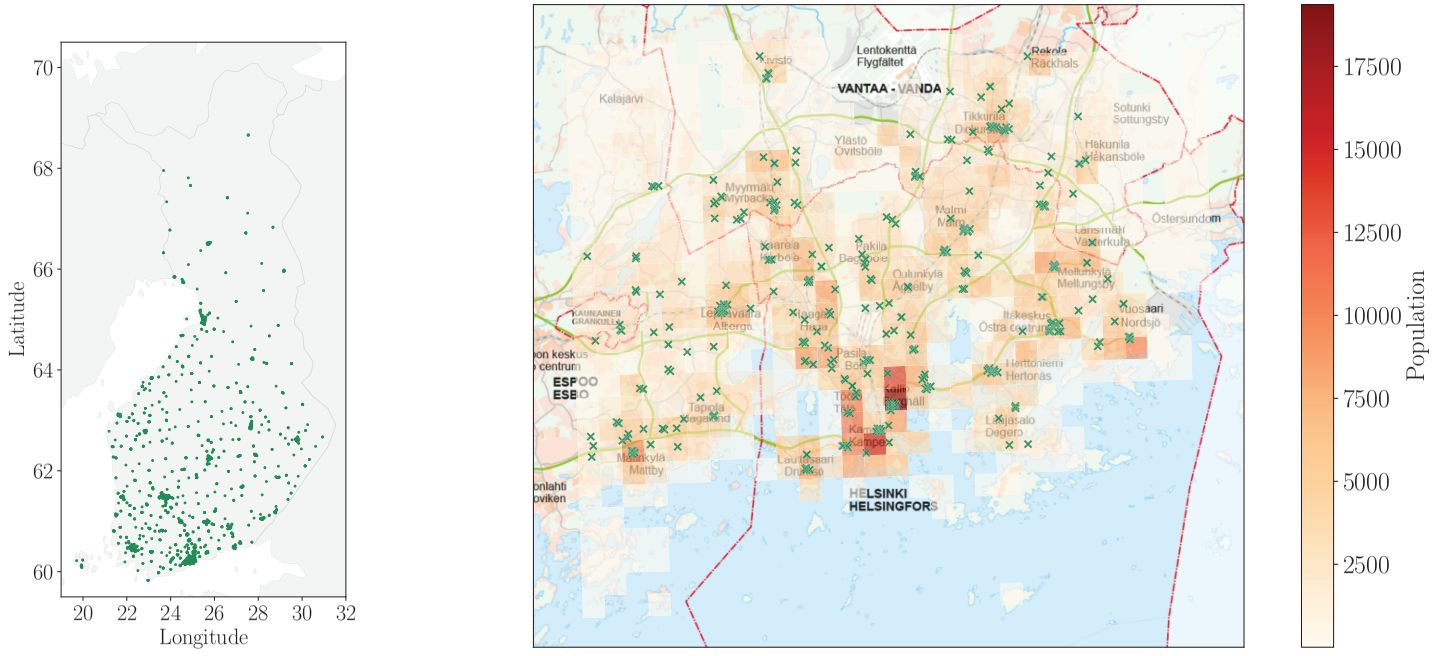
(a) Post Entry Game Map of HHIs

(b) Post Entry Game Map of HHI categories

Notes: The figure on the left shows the aggregated HHIs for all postal code areas in Finland. Gray areas denote loss of pharmacy access. Source: Statistics Finland (2021).

Figure B.5 displays the free entry counterfactual pharmacy network for whole Finland (Figure B.5a) and the Helsinki Capital Region (Figure B.5b). The main text Figure A.3a displays the map of Finland. In free entry counterfactual we see that most pharmacies enter locations that are on the fringes of densely populated locations. When a pharmacy is located outside a densely populated area, demand for its services comes from both the population center and the surrounding areas. This explains why only a few pharmacies are located in the centroids of the most populated areas (dark red in Figure B.5b), because then a large part of the demand would come from the highly populated area.

Figure B.5: Post-Entry Pharmacy Network



(a) Whole Finland

(b) Helsinki Capital Region

Notes: The figure on the left plots the post entry game pharmacy network in Finland. The figure on the right shows the same locations in Helsinki. Sources for the maps: Fimea (2021), Nominatim and OpenStreetMap contributors (2024), Statistics Finland (2023), Helsinki City Survey Services, Cities of Espoo, Vantaa, and Kauniainen (2022) and EuroGeographics (2024).

B.2 Pharmacy Regulation in the EU

Table B.1 shows an overview of pharmacy regulation in EU countries. Most countries impose restrictions on the number of pharmacy licenses issued, which are often based on the number of inhabitants per pharmacy. In most EU countries, pharmacy ownership is not restricted to pharmacists. However, in those countries where ownership is restricted to pharmacists, only Estonia, Hungary, and Poland allow a pharmacist to own multiple pharmacies. The amount of higher education required for pharmacy technicians or assistants ranges from none to four years with an average of 2.5 years. The degree of horizontal integration regulation varies between countries, with most countries allowing pharmacy chains. Bulgaria, Estonia, Hungary, Poland, and Portugal limit the chains to four pharmacies. Branch pharmacies and minority stakes are not included in horizontal integration. Most EU countries allow pharmacies to be owned by pharmaceutical wholesalers, making vertical integration possible. In particular, the regulation of horizontal and vertical integration is highly correlated, and in many countries, wholesalers also own pharmacy chains.

Table B.2 presents past pharmacy regulation policies focused on price setting, specifically in countries that do not regulate the number or location of pharmacies. The key takeaway is that even when a country allows more flexibility regarding pharmacy quantities or locations, some form of price regulation remains in place, and pharmacy pricing is rarely unregulated. The only exceptions are Sweden and Germany, where pharmacies have some discretion in pricing over-the-counter (OTC) drugs. This suggests that our free-entry counterfactual scenario with regulated pharmacy pricing closely mirrors an institutional framework with partial liberalization.

Table B.1: Pharmacy Regulation in the European Union (EU)

Country	Pharmacy Quantity	Pharmacy Location	Ownership Limits	Tech Educ.	Integration Horz.	Integration Vert.
Austria	Yes	Yes	Yes	2–3 y	No	No
Belgium	Yes	Yes	No	3 y	Yes	Yes
Bulgaria	No	No	No	3 y	Yes*	Yes
Croatia	Yes	Yes	No	4 y	Yes	Yes
Cyprus	No	Yes	Yes	None	No	No
Czechia	No	No	No	3 y	Yes	Yes
Denmark	Yes	Yes	Yes	3 y	No	No
Estonia	Yes	Yes	Yes	3 y	Yes*	No
Finland	Yes	Yes	Yes	3 y	No	No
France	Yes	Yes	Yes	2 y	No	No
Germany	No	No	Yes	2.5 y	No	No
Greece	Yes	Yes	No	2 y	Yes	Yes
Hungary	Yes	Yes	Yes	None	Yes*	No
Ireland	No	No	No	2 y	Yes	Yes
Italy	Yes	Yes	No	-	Yes	Yes
Latvia	Yes	Yes	No	2.5 y	Yes	Yes
Lithuania	No	Yes	No	3 y	Yes	Yes
Luxembourg	Yes	Yes	-	-	-	-
Malta	Yes	Yes	No	2 y	Yes*	Yes
Netherlands	No	No	No	2 y	Yes	Yes
Poland	Yes	Yes	Yes	2 y	Yes*	No
Portugal	Yes	Yes	No	4 y	Yes*	Yes
Romania	Yes	Yes	No	3 y	Yes	Yes
Slovakia	-	Yes	No	-	No	-
Slovenia	Yes	Yes	No	4 y	No	No
Spain	Yes	Yes	Yes	2 y	No	No
Sweden	No	Yes	No	<2 y	Yes	Yes

Notes: Overview of pharmacy regulation in the EU. "Pharmacy Quantity" refers to restrictions on the number of pharmacies that can operate. "Pharmacy Location" indicates restrictions on pharmacy locations. "Ownership Limits" describes whether ownership is limited to pharmacists. "Tech Educ." refers to the education requirements for pharmacy technicians in years. "Integration (Horz. & Vert.)" reflects the allowance of horizontal and vertical integration within the pharmacy sector. *Limited to four pharmacies, or one per town for Malta. Source: World Health Organization (2019).

Table B.2: Pharmacy Market Deregulation and Pricing in the EU

Country	Price Regulation	Free Pricing
Bulgaria	Yes	No
Cyprus	Yes	No
Czechia	Yes	No
Germany	Yes	No (RX), Yes (Non-RX)
Ireland	Yes	No
Lithuania	Yes	No
Netherlands	Yes	No
Slovakia	Yes	No
Sweden	Yes	No, Yes (OTC)

Notes: This table provides price regulation information for countries listed in Appendix Table B.1 that have implemented some form of entry deregulation. "Price Regulation" refers to existence of price regulation policies when some part of the pharmacy market entry regulation is lifted. "Free Pricing" refers whether pharmacies can set prices freely or not. Sources; Bulgaria: (Rohova, Dimova, Mutafova, Atanasova, Koeva, Ginneken et al. 2013; Dimova, Rohova, Atanasova, Kawalec and Czok 2017; Medicines for Europe 2022, 2023; Vogler, Arts and Habl 2006) Cyprus: (Zimmermann and Haasis 2021; Medicines for Europe 2023; Kanavos and Wouters 2014) Czechia: (Skoupá 2017; Medicines for Europe 2022, 2023) Germany: (Reese and Kemmner 2023; Medicines for Europe 2022, 2023) Ireland: (Medicines for Europe 2022, 2023; Doyle-Rossi and Gallagher 2023; Vogler, Arts and Habl 2006) Lithuania: (Enterprises 2021; Medicines for Europe 2022, 2023) Netherlands: (Zuidberg, Vogler and Mantel 2010; Medicines for Europe 2022, 2023) Slovakia:(Smatana, Pažitnỳ, Kandilaki, Laktišová, sdláková, Palušková, Ginneken and Spranger 2016; Medicines for Europe 2022, 2023) Sweden: (Medicines for Europe 2022, 2023; Panteli, Arickx, Cleemput, Dedet, Eckhardt, Fogarty, Gerkens, Henschke, Hislop, Jommi et al. 2016)

Table B.3: Data Sources

Data	Source	Open source	Usage
Pharmacy accounting data	Fimea	No	Analysis
Grid Database	Statistics Finland	No	Analysis
Zip-code RX expenditure	Kela	No	Analysis
Zip-code pharmacy visits	Kela	No	Analysis
Community structure data	SYKE	Yes	Analysis
Urban/Rural classifications	SYKE	Yes	Analysis
Pharmacy register	Fimea	Yes	Analysis, Maps
Country boundaries	EuroGeographics	Yes	Maps
Population Grid Data 1 km × 1 km	Statistics Finland	Yes	Maps
Paavo postal code area data	Statistics Finland	Yes	Analysis, Maps
Helsinki Metropolitan Area map	Helsinki	Yes	Maps
Pharmacy addresses, local amenities and travel distances	OpenStreetMap contributors	Yes	Analysis, Maps

Notes: This table lists our data sources. The first three sources are proprietary and used in the empirical estimations. We use publicly available data to calculate distances and travel times, to characterize population at the post code-level and as well as for plotting maps.

B.3 Data Sources

We list our data sources in Table B.3. The first three data sources are proprietary data from Fimea, Statistics Finland, and Kela. The grid database is a commercial product available for purchase. In addition to this data, we use publicly available data from several institutions and open source projects. Data from SYKE cover several classifications for the urban and rural characterization of the cells. For further information, see Finnish Environment Institute (2021a, 2021b).

Most importantly, we use several data sources and software from various OpenStreetMap contributors and projects. We use Nominatim and OpenStreetMap contributors (2024) data and software to map our pharmacy addresses to geoloca-

tions. We use OverPy and OpenStreetMap contributors (2024) data and software to locate nearby amenities for all pharmacies and our entry game locations. Finally, we use Geofabrik and OpenStreetMap contributors (2024) data to compute the travel time distances between the cells and pharmacies or the cells and the entry locations. We describe the computation of these distances in the next subsection.

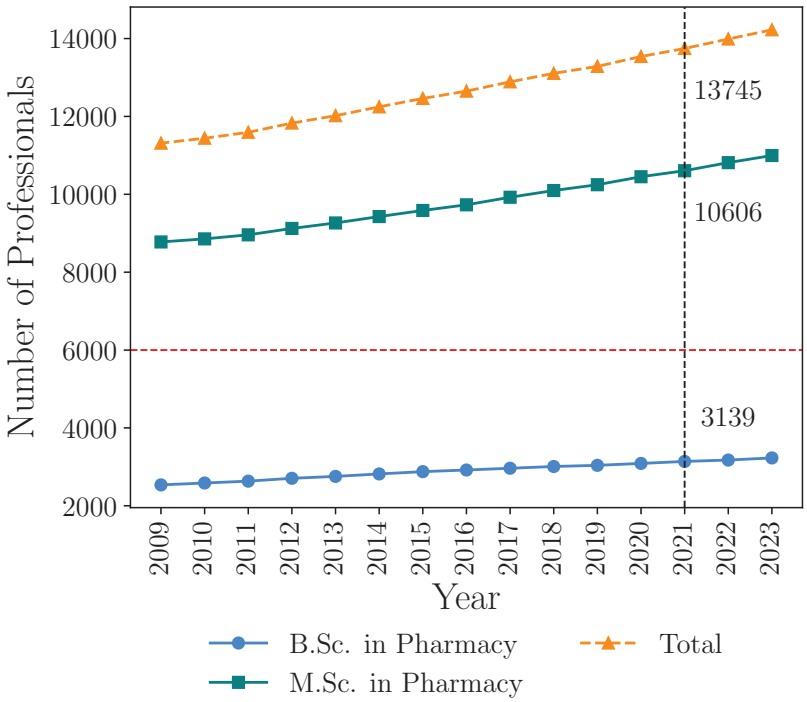
B.4 Travel Time Distances

We use the open source route planner OpenRouteService (2024) to calculate the travel distances between the pharmacy and the cells in its catchment area. We also repeat this for all the possible entry locations and their catchment areas. Due to the large number of cells and destinations (more than fifty million distances), we do not use the publicly available API. Instead, we run the OpenRouteService (2024) as a local instance from their pre-build Docker image. The travel distances are computed for car travel for all cells within 80 kilometer Euclidean distance from every pharmacy and entry location. We use the default options of the OpenRouteService (2024) image and do not use elevation data.

B.5 Number of Pharmacists

We present the number of pharmacists in Figure B.6. The figure shows a steady increase in the number of individuals with a university degree in Pharmacy in Finland. It also indicates some slack in the labor market, as the supply of university-educated professionals appears sufficient. Therefore, we do not anticipate significant concerns about a shortage of pharmacists under a free-entry market structure. However, it is important to note that our approximation does not account for potential wage increases driven by higher labor demand.

Figure B.6: Number of Pharmacists, B.Sc. and M.Sc. in Pharmacy



Notes: The figure shows the number of pharmacists under the age of 65 in Finland, categorized by their education level, from 2009 to 2023. The red dashed line indicates the approximate number of pharmacists needed under our free entry market structure, whereas the black dashed line marks the year for which data is available. Source: National Supervisory Authority for Welfare and Health of Finland (2024).

B.6 Analytical Gradients

In this section, we present the derivations for the analytical gradients we employ in our estimation procedure. Our objective function is:

$$\log\left(\hat{R}_s(\theta,\alpha)\right) - \log(R_s) \tag{23}$$

with $\theta = (\beta, \sigma)$. We omit the squared part of the log difference from equation (12) because `scipy.optimize.least_squares` requires the objective fuction and gradients in this form. Take derivative with respect to θ:

$$\frac{1}{\hat{R}} \times \frac{\partial \hat{R}_s(\theta,\alpha)}{\partial\theta} = \frac{1}{\hat{R}} \times \frac{\partial \sum_t R_{st}(\theta,\alpha)}{\partial\theta} \tag{24}$$

$$= \frac{1}{\hat{R}} \times \frac{\partial \sum_t \alpha \times N_t \times p_{st}(\theta)}{\partial\theta} \tag{25}$$

$$= \frac{1}{\hat{R}} \times \alpha \times \sum_t N_t \frac{\partial p_{st}(\theta)}{\partial\theta}. \tag{26}$$

For the linear terms $\beta \in \theta$ we have the following expression for the partial derivative $\frac{\partial p_{st}(\theta)}{\partial\theta}$:

$$\frac{\partial p_{st}}{\partial\beta} = \int \frac{\frac{\partial \exp(u_{ist}(\theta))}{\partial\beta} \times \sum_k \exp(u_{ikt}(\theta)) - \exp(u_{ist}(\theta)) \times \frac{\partial \sum_k \exp(u_{ikt}(\theta))}{\partial\beta}}{\left[\sum_k \exp(u_{ikt}(\theta))\right]^2} d\nu \tag{27}$$

$$= \int \frac{\exp(u_{ist}(\theta)) \times x_{st} \times \sum_k \exp(u_{ikt}(\theta)) - \exp(u_{ist}(\theta)) \times \sum_k x_{kt} \exp(u_{ikt}(\theta))}{\left[\sum_k \exp(u_{ikt}(\theta))\right]^2} d\nu \tag{28}$$

$$= \int \frac{\exp(u_{ist}(\theta)) \times (x_{st} \sum_k \exp(u_{ikt}) - \sum_k x_{kt} \exp(u_{ikt}))}{\left[\sum_k \exp(u_{ikt}(\theta))\right]^2} d\nu. \tag{29}$$

$$= \int p_{ist}(\theta) \times \left(x_{st} - \frac{\sum_k x_{kt} \exp(u_{ikt})}{\sum_k \exp(u_{ikt})}\right) d\nu. \tag{30}$$

For the non-linear terms $\sigma \in \theta$ we simply replace x_{st} with $x_{ist} = x_{st} \times \nu_i$ to

obtain the partial derivative $\frac{\partial p_{st}}{\partial \theta}$.

The analytical gradients for the RCNL model are more complicated:

$$\frac{\partial p_{st}}{\partial \beta} = \int \frac{\partial p^h}{\partial \beta} \times p^n + p^h \times \frac{\partial p^n}{\partial \beta} d\nu. \tag{31}$$

where (with abusing our notation) p^h denotes the within-nest probability and p^n the nest choice probability from equation (6). The derivative for the first term is

$$\begin{aligned} \frac{\partial p^h}{\partial \beta} = & \frac{\exp\left(u_{ist}/\left(1-\rho\right)\right) \times \frac{x_{st}}{1-\rho} \times \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\left[\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\right]^2} \\ & - \frac{\exp\left(u_{ist}/\left(1-\rho\right)\right) \times \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right) \times \frac{x_{kt}}{1-\rho}}{\left[\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\right]^2}, \end{aligned} \tag{32}$$

which simplifies to

$$= p^h \times \left(\frac{x_{st}}{1-\rho} - \frac{1}{1-\rho} \times \frac{\sum_k x_{kt} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)} \right). \tag{33}$$

The derivative for the second term is

$$\begin{aligned} \frac{\partial p^n}{\partial \beta} = & \frac{\left(1-\rho\right)\left(\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^{-\rho} \sum_k \frac{x_{kt}}{1-\rho} \exp\left(u_{ikt}/\left(1-\rho\right)\right) \exp\left(I_i\right)}{\left[\exp\left(I_i\right)\right]^2} \\ & - \frac{\exp\left(I_{ih(s)}\right)\left(1-\rho\right)\left(\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^{-\rho} \sum_k \frac{x_{kt}}{1-\rho} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\left[\exp\left(I_i\right)\right]^2}, \end{aligned} \tag{34}$$

which simplifies to

$$= p^n \times \left(1-p^n\right) \times \frac{\sum_k x_{kt} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)}. \tag{35}$$

Using equations (33) and (35), equation (31) becomes

$$\frac{\partial p_{st}}{\partial \beta} = \int p^h p^n \left(\frac{x_{st}}{1-\rho} - \frac{\sum_k x_{kt} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)} \left(\frac{1}{1-\rho} + \left(1-p_n\right) \right) \right) d\nu. \tag{36}$$

The partial derivative with respect to ρ is

$$\frac{\partial p_{st}}{\partial \rho} = \int \frac{\partial p^h}{\partial \rho} \times p^n + p^h \times \frac{\partial p^n}{\partial \rho} d\nu. \tag{37}$$

The derivative for the first term is

$$\begin{aligned} \frac{\partial p^h}{\partial \rho} = & \frac{u_{ist}}{(1-\rho)^2} \frac{\exp\left(u_{ist}/\left(1-\rho\right)\right) \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\left(\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^2} \\ & - \frac{\exp\left(u_{ist}/\left(1-\rho\right)\right)}{(1-\rho)^2} \frac{\sum_k u_{ikt} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\left(\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^2}, \end{aligned} \tag{38}$$

which simplifies to

$$= \frac{p^h}{(1-\rho)^2} \left(u_{ist} - \frac{\sum_k u_{ikt} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)} \right). \tag{39}$$

The derivative for the second term is

$$\frac{\partial p^n}{\partial \rho} = \frac{\frac{\partial I_{ih(s)}}{\partial \rho} \times \exp(I_{ih(s)}) \times \exp(I_i) - \frac{\partial I_i}{\partial \rho} \times \exp(I_i) \times \exp(I_{ih(s)})}{\exp(I_i)^2}, \tag{40}$$

where

$$\frac{\partial I_{ih(s)}}{\partial \rho} = -\ln \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right) + \frac{1}{1-\rho} \frac{\sum_k u_{ikt} \exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)} \tag{41}$$

and

$$\frac{\partial I_i}{\partial \rho} = p_n \times \frac{\partial I_{ih(s)}}{\partial \rho} \tag{42}$$

resulting in

$$\begin{aligned} \frac{\partial p^n}{\partial \rho} = & p^n \left(1 - p^n\right) \left(-\ln \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right) \right. \\ & \left. + \frac{1}{1-\rho} \frac{\sum_k \exp u_{ikt} \left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)} \right) \end{aligned} \tag{43}$$

Using equations (39) and (43), equation (37) becomes

$$\frac{\partial p_{st}}{\partial \rho} = \int p^h p^n \left(\frac{u_{ist}}{(1-\rho)^2} - (1-p^n) \ln \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right) \right.$$
$$\left. + \frac{1}{1-\rho} \times \frac{\sum_k \exp u_{ikt} \left(u_{ikt}/\left(1-\rho\right)\right)}{\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)} \times \left((1-p^n) - \frac{1}{1-\rho} \right) \right) d\nu. \tag{44}$$

B.7 Elasticity Formulas

In this section, we present the elasticity formulations for the random coefficients model. Let η^x_{srt} be the revenue elasticity of pharmacy s with respect to the characteristic x for pharmacy r in cell t. From equation (9) we obtain:

$$\eta^x_{srt} = \frac{\partial \hat{R}_{st}}{\partial x_{rt}} \times \frac{x_{rt}}{\hat{R}_{st}} \tag{45}$$

$$= \alpha \times N_t \times \frac{\partial p_{st}}{\partial x_{rt}} \times \frac{x_{rt}}{\hat{R}_{st}} \tag{46}$$

where $\frac{\partial p_{ist}(\theta)}{\partial x_{irt}}$ is the partial derivative of the choice probability of pharmacy s with respect to the characteristic x for pharmacy r. By the chain rule and the Leibniz integration rule:

$$\frac{\partial p_{st}(\theta)}{\partial x_{rt}} = \int \frac{\partial p_{ist}(\theta)}{\partial u_{irt}(\theta)} \times \frac{\partial u_{irt}(\theta)}{\partial x_{irt}} d\nu$$

$$= \int \frac{\mathbb{1}\left[s = r\right] \times \exp(u_{ist}(\theta)) \times \sum_k \exp(u_{ikt}(\theta)) - \exp(u_{ist}(\theta)) \times \exp(u_{irt}(\theta))}{\left[\sum_k \exp(u_{ikt}(\theta))\right]^2}$$
$$\times \frac{\partial u_{irt}(\theta)}{\partial x_{irt}} d\nu$$

$$= \int \frac{\exp(u_{ist}(\theta)) \times \left[\mathbb{1}\left[s = r\right] \times \sum_k \exp(u_{ikt}(\theta)) - \exp(u_{irt}(\theta))\right]}{\left[\sum_k \exp(u_{ikt}(\theta))\right]^2} \times \frac{\partial u_{irt}(\theta)}{\partial x_{irt}} d\nu$$

$$= \int p_{ist}(\theta) \left(\mathbb{1}\left[s = r\right] - p_{irt}(\theta)\right) \times \frac{\partial u_{irt}(\theta)}{\partial x_{irt}} d\nu$$
$$= p_{st}(\theta) \left(\mathbb{1}\left[s = r\right] - p_{rt}(\theta)\right) \times \left(\sum \theta^x\right) \tag{47}$$

where $\sum \theta^x$ represents all the terms associated with x (the main terms and the interactions). We can then present the elasticity as

$$\eta^x_{srt} = \alpha \times N_t \times p_{st}(\theta) \left(\mathbb{1}\left[s = r\right] - p_{rt}(\theta)\right) \times \left(\sum \theta^x\right) \times \frac{x_{rt}}{\hat{R}_{st}} \tag{48}$$

From equation (9) we had $\hat{R}_{st} = \alpha \times N_t \times p_{st}(\theta)$ so that equation (48) simplifies to

$$= \left(\mathbb{1}\left[s = r\right] - p_{rt}(\theta)\right) \times \left(\sum \theta^x\right) \times x_{rt}. \tag{49}$$

To obtain the elasticity formulations for the RCNL model, we begin with

$$\frac{\partial p_{st}(\theta)}{\partial x_{rt}} = \int \frac{\partial p^h_{ist}(\theta)}{\partial u_{irt}(\theta)} \times \frac{\partial u_{irt}(\theta)}{\partial x_{irt}} p^n + p^h_{ist} \frac{\partial p_n(\theta)}{\partial u_{irt}(\theta)} \times \frac{\partial u_{irt}(\theta)}{\partial x_{irt}} d\nu. \tag{50}$$

Because

$$\begin{aligned}\frac{\partial p_{ist}^{h}(\theta)}{\partial u_{irt}(\theta)} &= \frac{\mathbb{1}\left[s=r\right]\times\exp\left(u_{ist}/\left(1-\rho\right)\right)\times\sum_{k}\exp\left(u_{ikt}/\left(1-\rho\right)\right)}{\left(1-\rho\right)\times\left[\sum_{k}\exp(u_{ikt}(\theta)/(1-\rho))\right]^{2}} \\ &- \frac{\exp\left(u_{ist}/\left(1-\rho\right)\right))\times\left(\exp\left(u_{irt}/\left(1-\rho\right)\right)\right)}{\left(1-\rho\right)\times\left[\sum_{k}\exp(u_{ikt}(\theta)/(1-\rho))\right]^{2}} \\ &= \frac{p_{ist}^{h}}{\left(1-\rho\right)}\times\left(\mathbb{1}\left[s=r\right]-p_{irt}^{h}\right)\end{aligned} \tag{51}$$

and

$$\begin{aligned}\frac{\partial p^{n}(\theta)}{\partial u_{irt}(\theta)} &= \frac{\exp\left(u_{irt}/\left(1-\rho\right)\right)\left(\sum_{k}\exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^{-\rho}\exp\left(I_{i}\right)}{\left[\exp\left(I_{i}\right)\right]^{2}} \\ &- \frac{\exp\left(I_{ih(s)}\right)\exp\left(u_{irt}/\left(1-\rho\right)\right)\left(\sum_{k}\exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^{-\rho}}{\left[\exp\left(I_{i}\right)\right]^{2}}.\end{aligned} \tag{52}$$

Using the definition for p^n and adding a term $1/\sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)\times \sum_k \exp\left(u_{ikt}/\left(1-\rho\right)\right)$ we obtain

$$\begin{aligned}&= \left(1-p^{n}\right)\times\frac{1}{\sum_{k}\exp\left(u_{ikt}/\left(1-\rho\right)\right)}\times\sum_{k}\exp\left(u_{ikt}/\left(1-\rho\right)\right) \\ &\times\frac{\exp\left(u_{irt}/\left(1-\rho\right)\right)}{\exp\left(I_{i}\right)\left(\sum_{k}\exp\left(u_{ikt}/\left(1-\rho\right)\right)\right)^{\rho}}\end{aligned} \tag{53}$$

and

$$= \left(1-p^{n}\right)\times p_{irt}^{h}\times p^{n} \tag{54}$$

equation (50) becomes

$$\begin{aligned}\frac{\partial p_{st}(\theta)}{\partial x_{rt}} &= \int p_{ist}^{h}\times p^{n}\left[\frac{\mathbb{1}\left[s=r\right]}{1-\rho}+p_{irt}^{h}\left(1-\frac{1}{1-\rho}\right)-p_{irt}^{h}\times p^{n}\right]\frac{\partial u_{irt}(\theta)}{\partial x_{irt}}d\nu \\ &= p_{st}(\theta)\left[\frac{\mathbb{1}\left[s=r\right]}{1-\rho}+p_{rt}^{h}\left(1-\frac{1}{1-\rho}\right)-p_{rt}(\theta)\right]\times\left(\sum\theta^{x}\right),\end{aligned} \tag{55}$$

where $\sum \theta^x$ represents all the terms associated with x (the main terms and the

interactions). Substituting equations (55) and (9) into the elasticity formula (46), we obtain

$$\eta^x_{srt} = \left[\frac{\mathbb{1}[s=r]}{1-\rho} + p^h_{rt}\left(1 - \frac{1}{1-\rho}\right) - p_{rt}(\theta)\right] \times \left(\sum \theta^x\right) \times x_{rt}. \tag{56}$$

B.8 Diversion Ratios

In this section, we present the diversion ratios beginning with the random coefficients model. Using $\partial p_{ist}(\theta)/\partial u_{irt}(\theta)$ in Equation (47), the semielasticity of store s's revenue with respect to the utility of store $r \neq s$ is

$$\sigma_{s,r} = \frac{1}{\hat{R}_s}\sum_{t\in L_S} \alpha \times N_t \times \frac{\partial p_{st}}{\partial u_{rt}} = -\frac{1}{\hat{R}_s}\sum_{t\in L_S} \alpha \times N_t \times \int p_{ist}(\theta)p_{irt}(\theta)d\nu \tag{57}$$

and its own semielasticity is

$$\sigma_{s,s} = \frac{1}{\hat{R}_s}\sum_{t\in L_S} \alpha \times N_t \times \frac{\partial p_{st}}{\partial u_{st}} = \frac{1}{\hat{R}_s}\sum_{t\in L_S} \alpha \times N_t \times \int p_{ist}(\theta)\left(1 - p_{ist}(\theta)\right)d\nu. \tag{58}$$

As a result, we can define the store-level diversion ratios for each store as the proportion of decreased revenue from an improvement in the utility offered by store r that is diverted from store s (or, by symmetry, vice versa),

$$D_{s,r} = \frac{\sigma_{s,r}}{\sigma_{s,s}} = -\frac{\sum_{t\in L_S} N_t \times \int p_{ist}(\theta)p_{irt}(\theta)d\nu}{\sum_{t\in L_S} N_t \times \int p_{ist}(\theta)\left(1 - p_{ist}(\theta)\right)d\nu}. \tag{59}$$

To obtain the diversion ratios for the RCNL model, we use $\partial p_{ist}(\theta)/\partial u_{irt}(\theta)$ in Equation (55), and the semielasticity of store s's revenue with respect to the utility of store $r \neq s$ is

$$\begin{aligned}\sigma_{s,r} &= \frac{1}{\hat{R}_s}\sum_{t\in L_S} \alpha \times N_t \times \frac{\partial p_{st}}{\partial u_{rt}} \\ &= -\frac{1}{\hat{R}_s}\sum_{t\in L_S} \alpha \times N_t \times \int p^h_{ist} \times p^n \left[p^h_{irt}\left(\frac{\rho}{1-\rho}\right) + p^h_{irt} \times p^n\right] d\nu\end{aligned} \tag{60}$$

and its own semielasticity is

$$\begin{aligned}\sigma_{s,s} &= \frac{1}{\hat{R}_s}\sum_{t\in L_S}\alpha\times N_t\times\frac{\partial p_{st}}{\partial u_{st}}\\ &= \frac{1}{\hat{R}_s}\sum_{t\in L_S}\alpha\times N_t\times\int p^h_{ist}\times p^n\left[\frac{1}{1-\rho}+p^h_{irt}\left(1-\frac{1}{1-\rho}\right)-p^h_{irt}\times p^n\right]d\nu.\end{aligned} \tag{61}$$

As a result, we can define the store-level diversion ratios for each store as the proportion of decreased revenue from an improvement in the utility offered by store r that is diverted from store s (or, by symmetry, vice versa),

$$D_{s,r}=\frac{\sigma_{s,r}}{\sigma_{s,s}}=-\frac{\sum_{t\in L_S}N_t\times\int p^h_{ist}\times p^n\left[p^h_{irt}\left(\frac{\rho}{1-\rho}\right)+p^h_{irt}\times p^n\right]d\nu}{\sum_{t\in L_S}N_t\times\int p^h_{ist}\times p^n\left[\frac{1}{1-\rho}+p^h_{irt}\left(1-\frac{1}{1-\rho}\right)-p^h_{irt}\times p^n\right]d\nu}. \tag{62}$$

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