

Reference Pricing as a Focal Point: Evidence from the Finnish Pharmaceutical Market *

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Abstract

The reference price system adopted in the Finnish pharmaceutical market in 2009 initially decreased prices, but after a few years, firms learned to game the system, and prices gradually returned to their pre-reform level. How did firms succeed in raising prices, and what role did the regulation play in this process? We find that firms learned to use the previous quarter's reference price as a focal point when choosing prices at the beginning of each quarter; these prices determine the reference price for the whole quarter. Six big generic firms were more likely to follow this focal-point pricing rule, and their presence was associated with similar behavior among smaller rivals. According to our structural model, 65% of products have a profitable downward deviation from the upward pricing path but only 13% deviate. The remaining 52% suggest potential tacit coordination. On the positive side, we show that after the quarterly reference price is determined, it constrains firms from increasing prices higher.

JEL codes: L51, L13, L11, L65, I18

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1 Introduction

While price regulation is widely used with the objective of decreasing prices, it can inadvertently provide firms with a publicly observable focal point for coordination, as documented in markets such as credit cards, grocery, and gasoline (Knittel and Stango, 2003; Genakos et al., 2018; Martin and Verboven, 2026). The Finnish pharmaceutical reference price system provides a compelling institutional setting in which to study this coordination effect. Introduced in 2009, the system initially decreased prices, but after a few years, firms learned to game the system, and prices gradually returned to their pre-reform level. How did firms succeed in raising prices, and what role did the regulation play in this process? We find that many firms use the previous quarter’s reference price as a focal point for coordination, leading to price increases over time.

A key feature of the regulation is that the reference price for the whole quarter is determined by the lowest price at the beginning of the quarter plus an applicable price band¹. This regulation can facilitate reference price increases through the following mechanism: If all firms in a market choose prices equal to the previous quarter’s reference price at the beginning of the quarter, the new reference price increases by exactly the price band. By repeatedly following this focal-point pricing rule, firms can generate stepwise increases in the reference price from quarter to quarter. We document the focal-point pricing behavior for up to 60% of products and price-band-sized reference price increases in up to 30% of markets. Our main contribution is to explain the increase in the price level through firms’ focal-point pricing behavior.

Another key feature of the regulation is that firms can change their prices every two weeks, but the reference price is fixed for the whole quarter. Firms have a strong incentive to keep their prices at or below the reference price because pharmacies recommend only products priced at or below it, and consumers do not get reimbursed for the price difference above the reference price. After the reference price is fixed, only 7% of products are priced above it, and 50% of products are priced exactly at it. Our second contribution is to show that although the reference price facilitates coordination at the beginning of the quarter, it constrains firms from raising prices further within the quarter.

Using product-level wholesale data covering almost 1500 markets in 2009-2020, we find that the increase in the price level between 2012 and 2017 coincides with firms’ frequent use of the previous quarter’s reference price as a focal point. Six big generic firms, which we collectively refer to as the Big Six, are considerably more likely to follow the focal-point pricing rule than other firms. Our descriptive analysis shows that the Big Six are

¹Between 2009 and 2016, the price band was €1.5 or €2. Since 2017, the price band has been €0.5.

substantially different from other firms in terms of sales, the number of products supplied, the timing of price changes, and the tendency to undercut the previous reference price.

Our descriptive analysis of the focal-point pricing behavior documents three main findings. First, the share of markets with price-band-sized reference-price increases went from below 5% in 2009 to 23-30% in 2013-2016 before dropping to 10-15% after 2017. Second, the reference price is more likely to increase in markets containing only Big Six firms. Third, in markets containing both Big Six and other firms, a larger share of products supplied by the Big Six is positively correlated with the likelihood of a reference price increase.

Building on these findings, we estimate a structural model to study firms' pricing incentives and whether observed prices can be explained by competitive pricing or potential coordination. We first estimate a discrete-choice demand model that captures substitution across similar products within a market. Consumers choose a product within the market based on prices, whether a product is priced at or below the reference price, whether it is generic, branded, or parallel-imported. Our market definition follows the regulator's definition of a reference price group, which includes products with the same active ingredient, strength, dosage form, and package size group. For example, a market may contain all 10-mg 30-pill paracetamol products. Our demand estimates show that products priced at or below the reference price and branded products have higher market shares. Demand is more price elastic for products priced at or below the reference price than for products priced above it.

On the supply side, to construct marginal costs, we use each product's minimum observed price over the sample period, adjusted over time using a monthly producer price index. We do not recover marginal costs from firms' first-order conditions because of corner solutions: Products priced at the reference price have substantially higher sales than products priced just one cent above it. Therefore, the first-order conditions are not binding for products priced exactly at the reference price.

To model firms' pricing decisions, we distinguish between the beginning of the quarter, when the reference price is determined, and the remainder of the quarter, after the reference price is fixed. We begin by analyzing firms' incentives during the reference-price-setting period to check if observed prices are consistent with potential coordination. Although the reference-price-setting mechanism resembles a sealed-bid auction, our descriptive evidence shows substantial persistence in firms' prices: Firms submit prices that differ from their prices at the end of the previous quarter in only about 13% of observations. Assuming that all products submit prices equal to those at the end of the previous quarter, we calculate whether each product has an incentive to deviate downward by choosing a sufficiently low price to be the only product eligible for the full reimbursement and pharmacy recommendation at the beginning of the quarter. We then compare these deviation incentives with observed prices.

If a firm does not deviate despite having a profitable downward deviation, we interpret the observation as potential coordination. Analyzing firms’ incentives at the beginning of the quarter, our structural model suggests that 65% of products have a profitable downward deviation from the upward pricing path, but only 13% deviate. The remaining 52% suggest potential coordination.

We next study prices during the fixed-reference-price periods to examine whether the fixed reference price constrains prices. For products priced exactly at the reference price during these periods, we calculate whether they would increase their prices if they retained their reimbursement and pharmacy recommendation status. During the remainder of the quarter, we find that 83% of products observed at the reference price would increase their prices in the absence of the reference price. This result implies that, after the reference price is fixed, 83% of prices at the reference price can be rationalized by competitive pricing subject to the reference-price constraint. We obtain this estimate under the minimum-observed-price marginal cost assumption. Alternatively, under the assumption of zero marginal costs, we obtain a lower-bound estimate of 29%.

Taken together, our results suggest that, although the reference price system facilitates the focal-point pricing coordination and reference-price increases at the beginning of the quarter, the reference price also prevents many firms from increasing prices higher within the quarter. The price band reduction in 2017 has led to a decline in the focal-point pricing behavior at the product level and also price-band-sized reference-price increases at the market level. Our structural model offers an intuitive explanation for the effectiveness of the smaller price band after 2017. It is easier to undercut rivals sufficiently to push them above the reference price (and get the exclusive reimbursement and pharmacy recommendation status) when the price band is €0.5 than when it is €1.5 or €2. Based on our results, we recommend a further reduction in the price band while keeping the reference price fixed for the whole quarter.

Related Literature. Our first contribution is to the empirical literature on focal-point pricing and tacit coordination. While Knittel and Stango (2003) show how state-level interest-rate ceilings in the U.S. credit card market create a focal point for issuers, Genakos et al. (2018) provide evidence that the regulated maximum markup in the Greek fruit and vegetable market acts as a focal point for coordination. More recently, Martin and Verboven (2026) find that price caps in the Belgian retail gasoline market constrain only a minority of firms while inducing many firms to coordinate at the cap or at integer discounts below it. Our setting features a similar tradeoff but through a different regulatory mechanism of the reference price system in the Finnish pharmaceutical market.

Closest to our paper, Byrne and De Roos (2019) document a gradual transition to a

coordinated equilibrium in the retail gasoline market in Perth, Australia in which dominant firms use price leadership to create focal points and help rivals learn to coordinate. Similar to their approach, we begin by documenting heterogeneity in pricing behavior across firms. In particular, we show that six big generic firms are substantially more likely than other firms to use the previous reference price as a focal price at the beginning of the quarter. The difference of our setting is that firms do not need a dominant firm to create and signal the focal price, the regulation itself does it.

We also contribute to the literature on reference price regulation in pharmaceutical markets. [Kortelainen et al. \(2023\)](#) find that the Finnish reference price system decreased the expenditure per dose by 13% in the three years following its introduction in 2009. Other studies of pharmaceutical reference price systems also demonstrate that they strengthen price competition and reduce expenditures in Denmark ([Kaiser et al., 2014](#)), Norway ([Brekke et al., 2009, 2011](#)), and Sweden ([Granlund and Bergman, 2018](#)). Our paper complements this literature by showing that a reference price system can restrain prices while also creating focal points and facilitating price increases at the same time.

Finally, our paper contributes to the literature on pricing patterns and collusion in pharmaceutical markets. Previous studies document cartels in the US pharmaceutical market ([Clark et al., 2022](#); [Starc and Wollmann, 2025](#)), recurring price cycles in the Danish pharmaceutical market ([Hauschultz and Munk-Nielsen, 2020](#)), price dynamics in the Swedish pharmaceutical market ([Janssen, 2022](#)), and collusion through entry decisions in different package sizes ([Le and Toivanen, 2026](#)). Our paper is the first to identify the two sides of reference pricing: Restraining prices on the one hand, and providing a focal point for price coordination on the other hand.

Outline. The remainder of the paper is organized as follows. In Section 2, we describe the regulations and our data. In Section 3, we document the aggregate development of reference prices and the focal-point pricing behavior over time. In Section 4, we outline the differences between the Big Six and other firms. In Section 5, we present a descriptive analysis of the focal-point pricing behavior. In Section 6, we develop, estimate our structural model and discuss the results. In Section 7, we conclude.

2 Regulations and Data

2.1 Generic Substitution and Reference Price

Physicians prescribe pharmaceutical products by specifying the active ingredient, strength, dosage form, quantity required, and, in some cases, the firm name. Since the introduction

of generic substitution in Finland in April 2003, pharmacists have been required to offer patients the cheapest or nearly cheapest generic medicine suitable for substitution in place of the prescribed product.

In April 2009, the financial incentives for consumers to accept generic substitution were strengthened through the introduction of the reference price system. Pharmacies must offer a cheaper similar product if the prescribed product's price exceeds the reference price. If a consumer refuses to switch, they must pay the difference between the product's retail price and the reference price entirely out of pocket, unless the prescribing physician has prohibited substitution. This additional payment does not count toward the annual deductible or the out-of-pocket pharmaceutical expenditure used to determine reimbursement rates.

The regulator (Pharmaceuticals Pricing Board Hila) calculates a reference price for each reference price group on a quarterly basis. A reference price group consists of products with the same active ingredient, strength, dosage form, and package size group. The reference price is the lowest price among available products at the beginning of the quarter plus the applicable price band. Between 2009 and 2016, the price band was €1.5, or €2 when the VAT-inclusive price of the cheapest product exceeded €40. Since 2017, a uniform price band of €0.5 has applied to all reference price groups.

2.2 Price Setting

Pharmaceutical companies set uniform nationwide wholesale prices. Pharmacy markups are regulated by law and are weakly increasing in wholesale prices. Retail prices also include the value-added tax (VAT).

In addition to the reference price, regulations include maximum price caps. Reimbursable pharmaceuticals cannot be priced above the maximum price caps determined through negotiations between branded pharmaceutical firms and the regulator. For generic products, the price cap is set as a percentage of the branded product's price cap prior to generic entry. The current percentage is 40%.

Subject to these constraints, pharmaceutical companies update wholesale prices twice per month, on the first and fifteenth day of each month. Prices must be submitted in advance, and firms do not observe competitors' forthcoming pricing decisions before all prices are published simultaneously.

2.3 Reimbursement

The reimbursement rate for prescription pharmaceuticals depends on the severity of the condition and the consumer's annual out-of-pocket pharmaceutical expenditure. Consumers

have to pay out-of-pocket up to an initial annual deductible (currently €70) before receiving reimbursement. Depending on severity, the reimbursement rate ranges from 40% to 100%. After reaching the annual ceiling on out-of-pocket pharmaceutical expenditure (currently €636), consumers only need to pay a fixed fee of €2.50 for each reimbursable prescription pharmaceutical.

2.4 Data

Our first main dataset is monthly product-level wholesale sales and prices from April 2009 to December 2020 from the Finnish Medicines Agency (Fimea). Our second main dataset is semimonthly product-level price data from April 2009 to January 2022 from the Association of Finnish Pharmacists (AFP).

Both datasets include the Nordic Article Number (product id), market authorization holder (firm name), active ingredient, strength, package size, dosage form, and reference price group.

We use the semimonthly dataset for the descriptive analysis of prices. We use the monthly dataset for our structural model and analyses that require both price and sales data. In our demand estimation and Appendix event studies, we complement this data with monthly product-level wholesale data on sales and prices in Norway from April 2009 to October 2018 from Farmastat.

We also use data from the Finnish Pharmaceuticals Pricing Board (Hila) to exclude products with reported availability issues and reference price groups that are formed without generic competition.

3 The Development of Reference Prices and the Focal-point Pricing Behavior

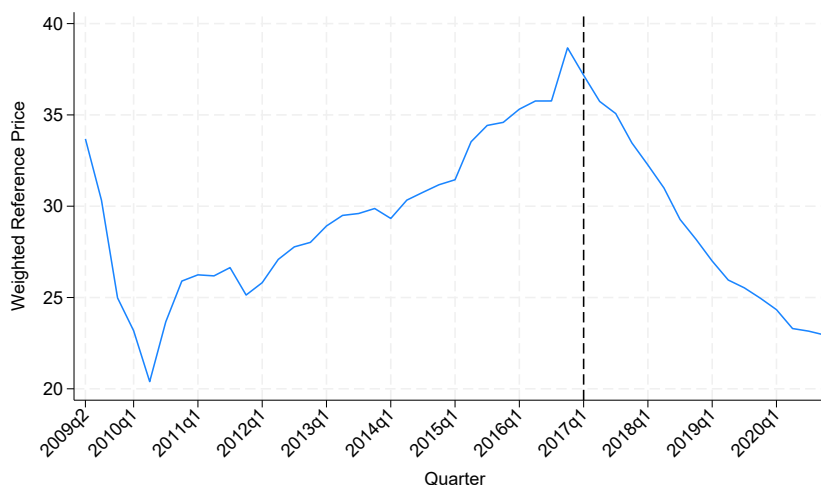
3.1 The Development of Reference Prices

We start by analyzing the development of the average reference price from the introduction of the reference price system in 2009 until 2020. In Figure 1, we plot the sales-weighted average reference price from 2009 to 2020. The sales used for weighting are from 2016Q4

before the price band was reduced to €0.5 in 2017^{2,3}. We find that the adoption of the reference price system in 2009 initially decreased the price level substantially, but by 2016 the price level had returned to its pre-reform level.

Reference prices dropped sharply following the introduction of the reference price system in 2009, consistent with previous literature showing that the 2009 reform reduced average expenditure per dose in the Finnish pharmaceutical market in the 36 months after its introduction (Kortelainen et al., 2023). Between 2011 and 2017, reference prices gradually increased to levels above those observed in 2009. This increase coincides with firms’ frequent use of the previous quarter’s reference price as a focal point (Figure 3 below). In 2017, the price band was reduced from €1.5/€2 to €0.5, after which reference prices began to decline. This decline coincides with a reduction in firms’ use of focal-point pricing (Figure 3 below). Our objective is to explain this reference price pattern through firms’ focal-point pricing behavior.

FIGURE 1: AVERAGE REFERENCE PRICE



Notes: Weighted by sales in 2016q4. Data source: AFP (2009—2022), Hila (2009–2022), Fimea (2009–2020).

3.2 Illustrative Market of the Focal-point Pricing Behavior

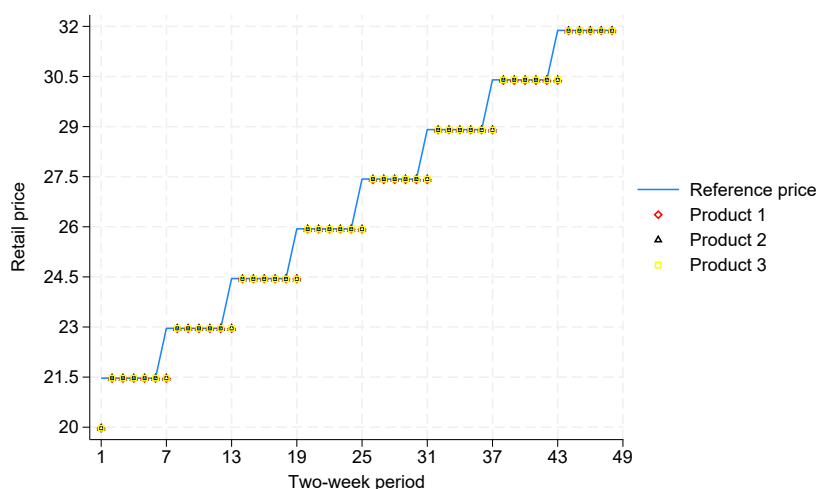
We illustrate the tacit coordination mechanism with an example market from the data where we observe the focal-point pricing behavior. Figure 2 plots two-week prices in one market

²In July 2016, the regulator also lowered the price caps of some branded products to the level applying to generic products. However, affected branded products at the price cap do not determine the minimum price in their reference price groups and therefore do not affect reference prices.

³As a robustness check, Figure A-1 in the Appendix presents average reference price weighted by the number of sold packages in 2016Q4. The resulting pattern is qualitatively similar.

from 2014 to 2016. At the beginning of each quarter of the year (two-week period 1, 7, 13, etc. in Figure 2), all three firms frequently submit prices exactly equal to the previous quarter’s reference price. As a result, the previous quarter’s reference price becomes the minimum price at the beginning of the quarter. Since the new reference price is calculated by adding a price band (€1.5 in this market) to the minimum price, the reference price then increases mechanically by €1.5. Once the reference price is fixed for the entire quarter, all firms increase their prices by €1.5 to match it. They then keep their prices unchanged for the remainder of the quarter and submit the same prices at the beginning of the next quarter. Over two years, prices in this market rise from €20 to €32, i.e., by 60%.⁴

FIGURE 2: PRICES IN A MARKET



Notes: Data source: AFP (2014-2016).

While this market nicely illustrates how the reference price system offers a focal point for firms to coordinate, it is an extreme example from the data. We next turn to a more thorough analysis of the focal point pricing behavior.

3.3 The Development of the Focal-point Pricing Behavior

We next document that pricing at the previous quarter’s reference price is a systematic feature of the Finnish pharmaceutical market rather than an isolated phenomenon in one reference price group. Figure 3 focuses on prices at the beginning of each quarter and shows

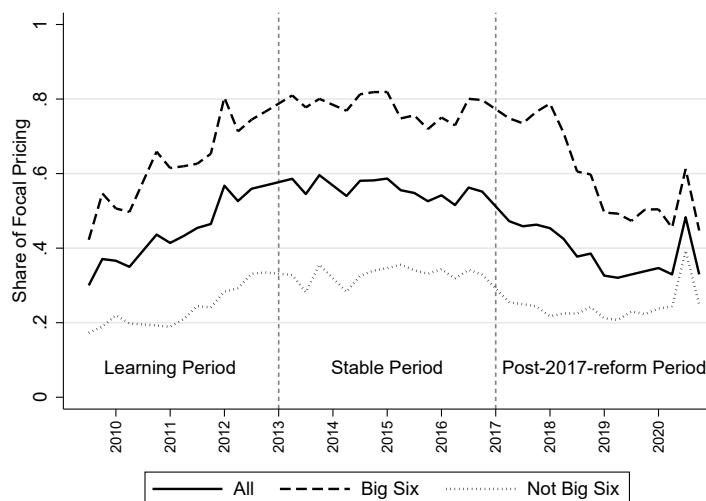
⁴Our data for this market cover a longer period than the two years shown in Figure 2. In Appendix Figure A-2, we plot the reference price and the number of firms for this reference price group from 2009 to 2020. The reference price closely follows the aggregate pattern shown in Figure 1: The reference price first declines after the 2009 reform, then rises steadily until 2017, and subsequently declines again.

that a substantial share of products are priced exactly at the previous quarter's reference price.

We refer to this pricing behavior as the focal-point pricing behavior and report the share of products following this price rule with the solid line. This share rises sharply from around 30% in 2009 to roughly 60% by 2012. We refer to this period as the Learning Period. The share then remains relatively stable at around 60% between 2013 and 2016, which we call the Stable Period. The Stable Period coincides with the upward trend in reference prices shown in Figure 1. Following the 2017 reduction in the price band to €0.5, the share declines from around 60% to approximately 35%. We refer to the period with the narrower price band as the Post-2017-reform Period. The weakening of focal-point pricing after the reduction in the price band also coincides with the decline in reference prices shown in Figure 1.

The prevalence of the focal-point pricing behavior also varies substantially across firms, as shown in Figure 3. In particular, the dashed line shows that products supplied by six big generic firms, which we collectively refer to as the Big Six, are considerably more likely to follow the focal-point pricing rule than products supplied by other firms, shown by the dotted line. In Figure 3, among Big Six firms, the share of products following focal-point pricing doubles from around 40% in 2009 to around 80% during the Stable Period before declining back to around 40% by 2020. In the following Section 4, our descriptive analysis of the Big Six will show that they are substantially different from other firms.

FIGURE 3: SHARE OF PRODUCTS WITH FOCAL-POINT PRICING



Notes: Unit of observations: Product-by-quarter. Prices at the beginning of the quarter. Products whose prices are always at the price caps and monopoly products are excluded. Data source: Fimea (2009–2020).

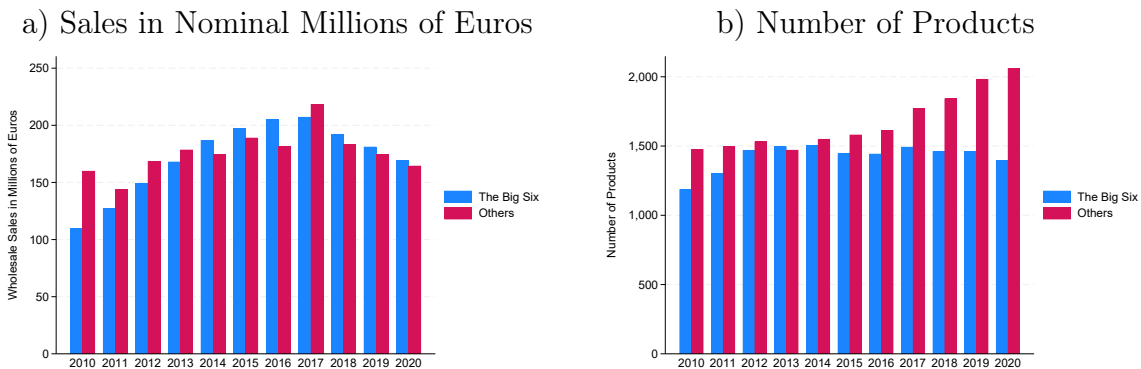
4 The Big Six

We define the Big Six as a group of six big generic firms. Figure 3 in the previous section shows that these firms are considerably more likely than other firms to follow the focal-point pricing rule at the beginning of the quarter, in particular by pricing at the previous reference price. The following subsections document three features that distinguish the Big Six from other firms in the market. First, we show that the Big Six are among the largest firms in the Finnish reference price system in terms of both sales and the number of products supplied. Second, we examine the timing of price changes and show that the Big Six are less likely to change their prices at the turn of each quarter (when prices determine the new reference price). Finally, we examine prices at the beginning of the quarter and show that the Big Six are less likely to undercut the previous reference price substantially to reduce the reference price.

4.1 Sales and Number of Products

The Big Six constitute an economically important part of the Finnish reference price system. Between 2011 and 2016, products supplied by the Big Six account for roughly half of total pharmaceutical sales in the reference price system, as shown in Figure 4a). Over the same period, the number of unique products supplied by the Big Six is approximately equal to the number supplied by all other firms combined, as shown in Figure 4b).

FIGURE 4: ANNUAL SALES AND NUMBER OF PRODUCTS



Notes: Figure a: Annual sales in wholesale prices. Figure b: Annual number of unique product numbers. Data Source: AFP (2010-2020), Fimea (2010-2020), Hila (2010-2020).

The distinction between the two groups is also apparent at the firm level. Table 1 shows that firms in the Big Six are substantially larger than firms outside the group. In 2013, a Big Six firm has, on average, 221 products and sales of 28 million euros, compared with 18

products and sales of 2.3 million euros for the average firm among other firms (a group of 76 firms). The difference is also evident in the medians: The median Big Six firm has 224 products and sales of 15.8 million euros, whereas the corresponding values among other firms are only 6 products and 0.8 million euros.

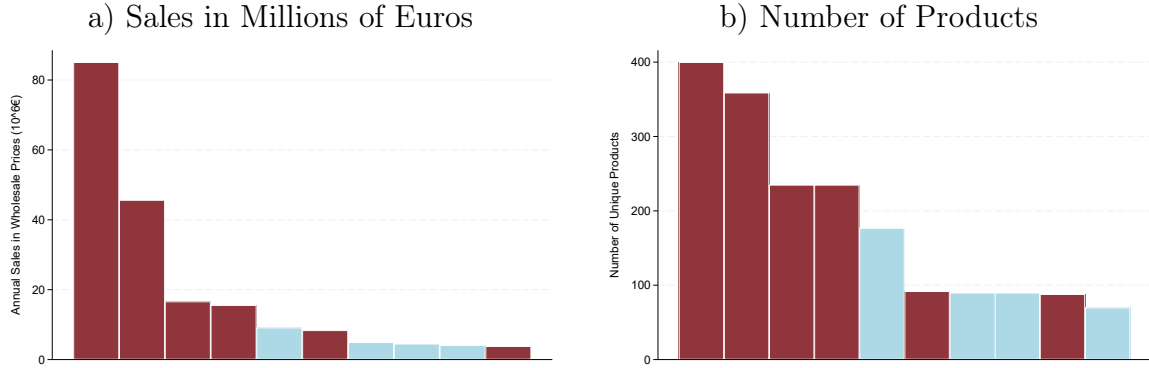
TABLE 1: FIRM-LEVEL SUMMARY STATISTICS BY FIRM GROUP IN 2013

Firm group	No. of Firms	No. of Products		Sales (Millions €)	
		Mean	Median	Mean	Median
Big Six	6	221	224	28.0	15.8
Other firms	76	18	6	2.3	0.8

Notes: Data Source: AFP (2013), Fimea (2013).

Figure 5 further illustrates this concentration by ranking the ten largest firms in 2013 by sales and number of products. The four largest firms under both measures belong to the Big Six (highlighted by the maroon bars). We also include the two smaller firms in the Big Six because each was subsequently merged with one of these four largest firms.⁵

FIGURE 5: FIRM-LEVEL ANNUAL SALES AND NUMBER OF PRODUCTS IN 2013 - TOP 10



Notes: Maroon bars: Big Six, blue bars: other firms. Figure a: Annual sales in wholesale prices. Figure b: Annual number of unique product numbers. Data Source: AFP (2013), Fimea (2013).

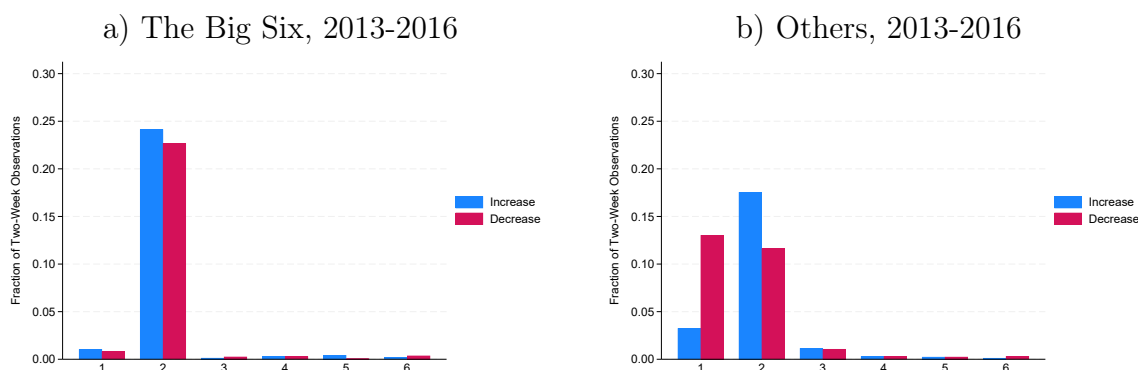
⁵To verify that the Big Six were already among the major firms when the reference price system was introduced, we conduct the same exercise for 2009 in Figure A-3 in the Appendix, ranking the ten largest market authorization holders by generic sales and by number of products. The results show that the Big Six were also among the largest firms at the beginning of the reference price regulation in 2009.

4.2 Timing of Price Changes

We illustrate how the pricing behavior of the Big Six differs from that of other firms in the timing and direction of price changes in Figure 6. The reference price is determined at the beginning of each quarter and remains fixed for the rest of the quarter, whereas firms may revise their prices twice per month. We therefore divide each quarter into six two-week periods. Only price changes made in the first two-week period affect the reference price for that quarter.

Figure 6 reports separately the fraction of products with a price increase and the fraction with a price decrease in each of the six two-week periods within a quarter in the Stable Period of 2013-2016. Bar cluster "1" captures price changes between the sixth two-week period of the previous quarter and the first two-week period of the current quarter, when prices determine the new reference price. At the beginning of the quarter, firms outside the Big Six are substantially more likely to reduce their prices in the first two-week period (13% of other firms compared to 1% of the Big Six, red bars of bar clusters "1" in both graphs), when price changes can affect the new reference price.

FIGURE 6: DISTRIBUTION OF THE TIMING OF PRICE CHANGES



Notes: x-axis: Two-week periods within a quarter. Data source: AFP (2013-2016).

Bar cluster "2" captures price changes between the first and second two-week periods, after the new reference price is known. For both the Big Six and other firms, price adjustments are concentrated in the second two-week period of the quarter. The total share of products with price changes in the second two-week period (sum of red and blue bars in bar clusters "2") is 47% for the Big Six and 29% for other firms. Many firms adjust their prices only after observing the newly established reference price.

Other bar clusters from "3" to "6" show that all firms rarely change their prices in the second and third month of each quarter. Figure 6 suggests that other firms are more likely to

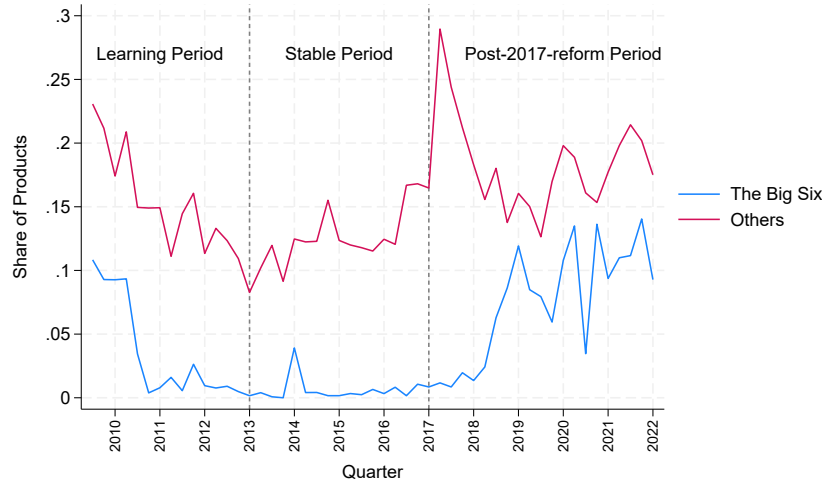
decrease prices at the beginning of the quarter, whereas the Big Six are more likely to wait until the new reference price is known before adjusting their prices in the second two-week period.

4.3 Prices at the Beginning of the Quarter

In the previous subsection, we have shown that other firms are more likely to decrease prices than the Big Six at the beginning of the quarter. Are other firms trying to decrease the minimum price (and hence the reference price)? In this subsection, we examine the share of products that choose a price at the beginning of the quarter that is low enough to reduce the reference price.

In Figure 7, the red line represents the share of products with reference-price-decreasing prices for other firms, and the blue line represents this share for the Big Six. The red line is always higher than the blue line, which means other firms are more likely to decrease the reference price than the Big Six. In the Learning Period of 2009-2012, both shares declined. In the Stable Period of 2013-2016, the blue line is close to 0, indicating that the Big Six almost never choose a price that would reduce the reference price. In the Post-2017-reform period of a narrower price band, both lines increase.

FIGURE 7: SHARE OF PRODUCTS WITH REFERENCE-PRICE-DECREASING PRICES



Notes: Share of prices at the beginning of the quarter. Data source: AFP (2009–2022), Hila (2009–2022).

Figure 7 shows that other firms are consistently more likely to price sufficiently far below the previous reference price to reduce the reference price for the new quarter. The Big Six, by contrast, rarely make such bids.

Together with Figure 6 displaying the timing and direction of price changes, Figure 7 reveals a distinctive pricing pattern among the Big Six in the Stable Period of 2013-2016. These firms typically revise their prices in the second two-week period, after the new reference price is known. Then, they rarely make price changes during the remainder of the quarter. At the beginning of the next quarter, they are also very unlikely to revise prices and frequently submit prices at the previous reference price. The pricing behavior of firms outside the Big Six is different. These firms are more likely to change prices at the beginning of the quarter, when their prices can affect the reference price. Also, other firms are more likely to undercut the previous reference price substantially to reduce the reference price.

5 Descriptive Analysis of Focal-point Pricing

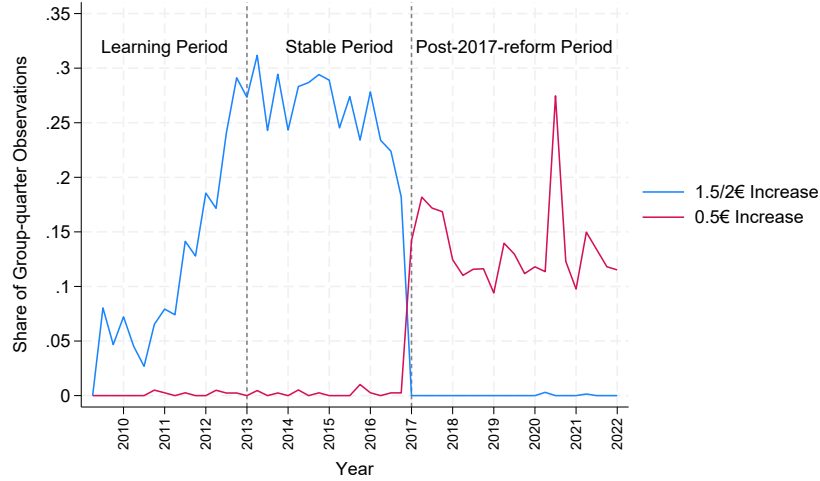
5.1 Price-band-sized Reference Price Increases

In Figure 3 in Section 3, we have shown at the product level that the share of products following the focal-point pricing rule increased from 30% in 2009 to 60% in 2012 and remained stable there until 2017 before dropping to 35%. In this section, we analyze market-level outcomes and report the share of markets in which firms succeed in raising the reference price by exactly the price band (conditional on the maximum price cap of the market not binding). For the focal-point pricing coordination to succeed, all firms in the market have to follow the focal-point pricing behavior at the beginning of the quarter.

Figure 8 reports the share of markets in which the reference price increases by exactly €1.5, €2, or €0.5. The blue line corresponds to reference-price increases of €1.5 or €2 (the pre-2017 price bands), while the red line corresponds to reference-price increases of €0.5 (the post-2017 price band).

In the Learning Period of 2009-2012, the share of markets with reference price increases of €1.5 or €2 increases from below 5% in 2009 to 25% in 2012. In the Stable Period of 2013-2016, 24%-30% of markets experience a reference price increase equal to the applicable price band of €1.5 or €2. In the first two periods, the share of markets with reference price increases of €0.5 is close to 0. In contrast, in the Post-2017-reform Period of the narrower price band, the share of markets with reference price increases of €0.5 is 10%-15%. In the last period, almost no markets have reference price increases of €1.5 or €2. Therefore, Figure 8 indicates that firms adjust their focal-point pricing behavior to the new price band after 2017, and that the applicable price band plays an important role in shaping market-level reference price increases.

FIGURE 8: PRICE-BAND-SIZED REFERENCE PRICE INCREASES



Notes: Annual share of reference-price-group-by-quarter with reference price increases equal to the price band or within 2 cents smaller. Markets with binding price caps are excluded. Data source: AFP (2009–2022).

5.2 Reference Price Reaching Maximum Price Cap

Pharmaceutical firms cannot price above the maximum price caps set by the regulator. If firms repeatedly use the focal-point pricing rule, the reference price increases quarter after quarter until it reaches the price cap. In this subsection, we study the likelihood of a market reaching its maximum price cap.

In order to analyze whether a market reaches the maximum price cap, it is useful to divide markets into three types. Type 3 markets have only Big Six firms, Type 2 markets have only non-Big Six firms, and Type 1 markets have a mix of both. Figure 9 plots the share of markets with binding price caps across the three types of markets and the three time periods.

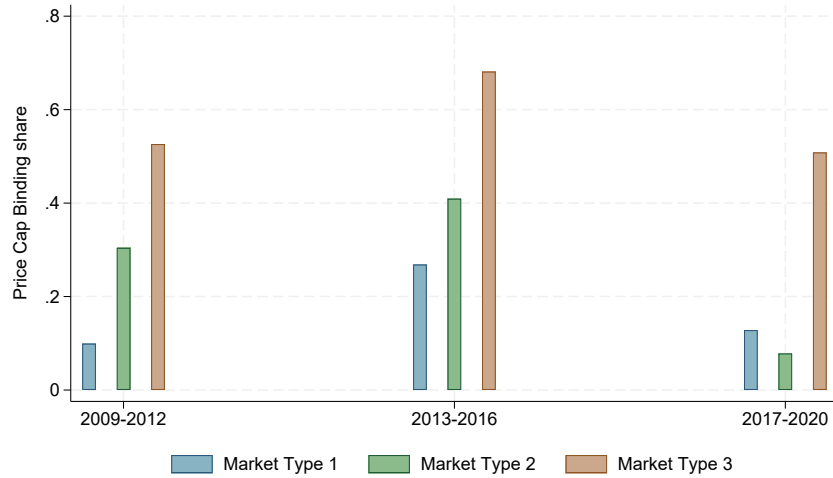
In the Learning Period of 2009-2012 depicted by the first bar cluster of Figure 9, Type 1 markets are the most common (417 markets) and have the lowest share with binding price caps, at 10% (first bar cluster, blue bar). By contrast, Type 3 markets are much less common (93 markets), and are much more likely to reach the price caps, with 53% binding (first bar cluster, green bar). Type 2 includes 65 markets, of which 30% have binding price caps (first bar cluster, orange bar).

In the Stable Period of 2013-2016, the share of markets with binding price caps increases across all market types: From 10% to 27% in Type 1 (second bar cluster, blue bar), from 30% to 41% in Type 2 (second bar cluster, green bar), from 53% to 68% in Type 3 (second bar cluster, orange bar).

After the reduction of the price band in 2017, the share of markets having binding price caps declines across all market types. The share goes from 27% to 13% in Type 1 (third bar cluster, blue bar), from 41% to 8% in Type 2 (third bar cluster, green bar), from 68% to 51% in Type 3 (third bar cluster, orange bar).

Figure 9 shows that binding maximum price caps are particularly prevalent in markets with only Big Six firms (Type 3), and their prevalence declines after the 2017 reduction in the price band. For all market types, the share of markets with binding price caps increases from the Learning Period of 2009-2012 to the Stable Period of 2013-2016 and then declines in the Post-2017 Period.

FIGURE 9: SHARE OF MARKETS WITH BINDING PRICE CAPS



Notes: Unit of observation: Reference-price-group-by-quarter. Markets with monopoly products are excluded. Data source: Fimea (2009–2020).

5.3 Reference Price and the Number of Firms

Because a price-band-sized reference price increase requires all firms in the market to have the focal-point pricing behavior, we study how the number of firms in a market affects market-level outcomes. In Table 2, we present the probability of price-band-sized reference price increases and binding price caps by the number of firms (Panel A) and the number of firms outside of the Big Six (Panel B). We exclude the Learning Period and focus on the Stable Period of 2013-2016 and the Post-2017-reform Period of 2017-2020.

In Panel A, the first row shows the shares of markets in the Stable Period of 2013-2016 having price-band-sized reference price increases conditional on the maximum price cap not binding. During the Stable Period of 2013-2016, more than 22% of the time, firms succeed

in having price-band-sized reference price increases even when there are more than 3 firms in the market. The second row shows the same shares in the Post-2017-reform Period. The overall share ("All" Column) declines from 26% in the Stable Period to 14% in the Post-2017-reform Period. Conditional on the number of firms, the shares are larger in 2013-2016 than in 2017-2020 across all values of the number of firms (Panel A, first and second rows).

In Panel A, the third and fourth rows show the shares of markets having binding maximum price caps. The overall share ("All" Column) declines from 51% in the Stable Period to 34% in the Post-2017-reform Period. Conditional on the number of firms, the shares are larger in 2013-2016 than in 2017-2020 across all values of the number of firms (Panel A, third and fourth rows). In both rows, the share of markets having binding maximum price caps is decreasing in the number of firms.

In Panel B, the first and second rows show the shares of markets having price-band-sized reference price increases conditional on the maximum price cap not binding. The third and fourth rows show the shares of markets having binding maximum price caps. In all rows, the shares of markets having price-band-sized reference price increases or having binding maximum price caps are decreasing in the number of firms outside the Big Six.

TABLE 2: SHARE OF MARKETS WITH PRICE-BAND-SIZED REFERENCE PRICE INCREASES OR BINDING PRICE CAPS

Panel A		Number of Firms							
	Years	All	1	2	3	4	5	5+	
PB-Sized Increase	2013–2016	.26	.28	.19	.22	.36	.32	.23	
	2017–2020	.14	.18	.18	.16	.15	.11	.05	
Binding Price Cap	2013–2016	.51	.82	.71	.5	.4	.27	.07	
	2017–2020	.34	.71	.48	.27	.18	.06	.01	
Panel B		Number of Firms outside the Big Six							
	Years	All	0	1	2	3	4	5	5+
PB-Sized Increase	2013–2016	.26	.39	.34	.25	.23	.19	.12	.06
	2017–2020	.14	.29	.23	.13	.07	.06	.02	.02
Binding Price Cap	2013–2016	.51	.85	.7	.41	.15	.03	0	0
	2017–2020	.34	.63	.56	.2	.06	.04	0	0

Notes: Unit of observation: Reference-price-group-by-quarter. PB-Sized Increase: Price-band-sized reference price increase. The PB-Sized Increase rows are conditional on markets without binding price caps. Data Source: AFP (2013–2020), Hila (2013–2020).

5.4 Descriptive Regressions of Reference Price Changes

In addition to the previous descriptive analysis, we estimate the following descriptive regressions to analyze which markets are more likely to have a reference price increase.

$$RPIncrease_{mt} = \alpha_0 Type2_{mt} + \alpha_1 Type3_{mt} + \beta_0 RPRatio1_{mt} + \beta_1 RPRatio2_{mt} + \beta_2 RPRatio3_{mt} + \gamma Big6Ratio_{mt} + \delta_0 Market_m + \delta_1 Time_t \quad (1)$$

The dependent variable $RPIncrease_{mt}$ is a dummy (0/1) indicating whether the market has a reference price increase. The first group of explanatory variables consists of last quarter's market type dummies (0/1) $Type2_{mt}$ and $Type3_{mt}$. Type 1 markets are omitted as the baseline. The second group of explanatory variables $RPRatio1_{mt}$, $RPRatio2_{mt}$, $RPRatio3_{mt}$ are continuous variables equal to the last quarter's reference price divided by the maximum price cap conditional on last quarter's market type. The last explanatory variable is $Big6Ratio_{mt}$, which is the share of products from the Big Six in the market. This share is only relevant in Type 1 markets where there are both Big Six and other firms in the market.

Table 3 presents descriptive regressions of reference price increases in three panels with robust standard errors. The first panel of market types shows that Type 3 markets (only Big Six) are statistically more likely to have a reference price increase than the baseline Type 1 markets (mix of firms). This result also holds in the second specification when we do not control for other explanatory variables (Column 2).

The second panel of reference price ratios examines how the position of the previous reference price relative to the price cap affects subsequent reference-price changes. Firms cannot price above the maximum price cap. Across market types, a higher reference price/price cap ratio is associated with a lower probability of a reference price increase. This result is intuitive because there is less room for further increases when the reference price is already close to the maximum price cap.

The third panel of the Big Six ratio focuses on the composition of firms in the market. The estimate shows that a larger Big Six presence is associated with a higher probability of a reference price increase. This result suggests that greater exposure to Big Six firms facilitates an increase in the reference price.

Taken together, our descriptive regression results show that the reference price is more likely to increase when a market contains only Big Six firms, when the reference price is much lower than the maximum price cap, and when a mixed market has a large Big Six presence.

TABLE 3: DESCRIPTIVE REGRESSIONS OF REFERENCE PRICE INCREASES

	(1)	(2)
	RP Increase	RP Increase
	(0/1)	(0/1)
Panel 1: Market Type		
Type 2 (Only other firms)	.27*** (.04)	.02 (.02)
Type 3 (Only Big Six)	.83*** (.06)	.29*** (.02)
Panel 2: Reference Price / Price Cap Ratios		
Reference Price Ratio - Market Type 1 (Mix of firms)	-.38*** (.02)	
Reference Price Ratio - Type 2 (Only other firms)	-.50*** (.05)	
Reference Price Ratio - Type 3 (Only Big Six)	-.74*** (.07)	
Panel 3: Big Six Ratio		
Big Six Ratio - Type 1 (Mix of firms)	.41*** (.04)	
Quarter/Year FEs	Yes	Yes
Market FEs	Yes	Yes
Observations	17654	17654

Notes: Unit of observation: Reference-group-by-quarter. We exclude markets with binding price caps and monopoly markets. Robust SEs in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data source: Fimea (2009–2020).

6 Structural Model

Building on the findings of the previous descriptive analyses, we estimate a structural model to study firms' pricing incentives and whether observed prices can be explained by competitive pricing or potential coordination. We first estimate a discrete-choice demand model. Then, on the supply side, we distinguish between two periods. The first is the reference-price-setting period at the beginning of each quarter, when firms' submitted prices determine the new reference price. The second consists of the fixed-reference-price periods during the remainder of the quarter, after the reference price has already been fixed.

6.1 Demand

We estimate a discrete-choice demand model that captures substitution across similar products within the same market. Our market definition follows the regulator's definition of a reference price group. It includes all products with the same active ingredient–dosage form–strength–package size group and an outside good. We assume that there is no substitution across markets. The indirect utility for consumer i from buying product j is given by:

$$v_{ij} = \alpha + \gamma R_j - \beta_1 \ln(P_j | R_j = 1) - \beta_2 \ln(P_j | R_j = 0) + \kappa X_j + \xi_j + \epsilon_{ij} \quad (2)$$

where R_j is a dummy of whether product j 's price is at or below the reference price, P_j is the price of product j , X_j includes product characteristics such as being a branded product or a parallel import, ξ_j is product quality, which is observed by the consumer but unobserved by the econometrician. The consumer and product-specific taste shock ϵ_{ij} is i.i.d across products and follows the EV type 1 distribution. We normalize the utility from the outside good to zero.

The aggregate market share of product j is given by:

$$s_j = \frac{\exp(\alpha + \gamma R_j - \beta_1 \ln(P_j | R_j = 1) - \beta_2 \ln(P_j | R_j = 0) + \kappa X_j + \xi_j)}{1 + \sum_j \exp(\alpha + \gamma R_j - \beta_1 \ln(P_j | R_j = 1) - \beta_2 \ln(P_j | R_j = 0) + \kappa X_j + \xi_j)} \quad (3)$$

Because R_j is recorded only for the first month of the quarter in the data, we estimate demand using only data from those months. We assume that the demand parameters are the same in the first month and in the remaining months of the quarter. The key distinction between these periods is that, in the first month, the reference price is determined by the minimum price, whereas in subsequent months, the reference price is fixed. This distinction affects firms' pricing decisions, but it should not directly affect physicians' and consumers' choices among pharmaceutical products.

We estimate demand with price and quantity at the package level for all products in the Finnish pharmaceutical market’s reference price system. To address the endogeneity of prices, we construct a Hausman-style instrument by matching the prices of products in Finland to the prices of the same products in Norway. In the case of not finding a match, we impute prices based on a projection of observed prices in Norway on product characteristics. The intuition of our instrument is that the same product should have the same cost shock across the two countries, but that the demand shocks, conditional on our observables, are independent.

We estimate the following demand equation with monthly data, assuming an outside good’s market share of 5%.

$$\ln(s_{jt}) - \ln(s_{0t}) = \alpha + \gamma R_{jt} - \beta_1 \ln(P_{jt}|R_{jt} = 1) - \beta_2 \ln(P_{jt}|R_{jt} = 0) + \kappa X_{jt} + \xi_{jt} \quad (4)$$

We present results from the logit demand specification (Column 1) and the random coefficient logit demand specifications (Columns 2 and 3) in Table 4. We incorporate a random coefficient for the dummy of being priced at or below the reference price in Column (2) and for the log price variable for those products priced at or below the reference price in Column (3). For simplicity, we use the estimated demand parameters of the logit demand specification in Column (1) for calculations in the following subsections⁶.

All coefficients are precisely measured and of the expected sign. Being priced at or below the reference price and being a branded product lead to higher market shares, while being a parallel-imported product results in lower market shares. Demand is more price elastic for products priced at or below the reference price than for products priced above it.

6.2 Supply

On the supply side, to construct marginal costs, we use each product’s minimum observed price over the sample period, adjusted over time using a monthly producer price index for basic pharmaceutical products and pharmaceutical preparations from Statistics Finland. We do not recover marginal costs from firms’ first-order conditions for two reasons. The first reason is the presence of corner solutions: Products priced at the reference price have substantially higher sales than products priced just one cent above it. The second reason is that we want to explain observed prices with either competitive pricing or potential coordination. We therefore impose marginal cost assumptions to infer the conduct underlying observed prices instead of recovering marginal costs from competitive pricing’s first-order conditions.

⁶We plan to use the estimates from the random coefficient logit demand specification for calculations in the following subsections in the near future.

TABLE 4: DEMAND ESTIMATION

	(1)	(2)	(3)
	Logit	RC Logit	RC Logit
At or below reference price (0/1)	7.83*** (.65)	9.53*** (1.17)	9.87*** (1.32)
At or below reference price σ		1.93*** (.66)	
log(Price) At or below reference price	-2.01*** (.23)	-2.14*** (.26)	-2.31*** (.30)
log(Price) σ At or below reference price			0.65*** (.24)
log(Price) Above reference price	-1.22*** (.11)	-1.30*** (.13)	-1.33*** (.14)
Branded	4.02*** (.18)	4.67*** (.42)	4.71*** (.44)
Parallel Import	-.81*** (.09)	-1.57*** (.45)	-1.67*** (.52)
Month FEs	Yes	Yes	Yes
Market FEs	Yes	Yes	Yes
Observations	80171	80171	80171

Notes: Observations are at the product level. The base category is Generic. Robust SEs in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data source: Fimea (2009–2020).

To model firms' pricing decisions, we distinguish between the beginning of the quarter, when the reference price is determined, and the remainder of the quarter, after the reference price is fixed. When the reference price is fixed in the second and third month of the quarter, the profit maximization problem in month t is the following.

$$\max_{P_{jt}} (P_{jt} - c_{jt}) \times s_{jt} \quad (5)$$

At the beginning of the quarter, firms' prices affect the reference price for the whole quarter. Therefore, their profit maximization problem at the beginning of the quarter also includes the profits in the second and third months of the quarter.

$$\max_{P_{j,t}} (P_{j,t} - c_{j,t}) \times s_{j,t} + \sum_{t'=2}^3 (P_{j,t'} - c_{j,t'}) \times s_{j,t'} \quad (6)$$

6.3 Reference-price-setting Prices

In this subsection, we focus on prices at the beginning of the quarter and examine whether a firm has incentives to submit a sufficiently low price to become the only product eligible for full reimbursement and pharmacy recommendation. We then compare these deviation incentives with observed prices. If such a downward deviation would be profitable but the firm does not deviate in the data, we interpret the observed pricing behavior as potential coordination.

We calculate the deviation incentives as follows. Although the reference-price-setting mechanism is designed as a first-price sealed-bid auction, our descriptive evidence shows substantial persistence in firms' prices: Firms submit prices that differ from their prices at the end of the previous quarter in only about 13% of observations. Assuming that all products submit prices equal to their prices at the end of the previous quarter, we calculate the expected market share in the first month $\widehat{s}_{j,t}$ when a firm deviates and chooses price $\widehat{P}_{j,t} = \min_{k \neq j} \widehat{P}_{k,t} - PriceBand - \epsilon$ at the beginning of the quarter.

A firm considering such a deviation must also take into account its effect on the reference price for the remainder of the quarter. A sufficiently large downward deviation lowers the reference price and can therefore induce subsequent price adjustments by other products. In each deviation scenario, we assume that the prices of all products during the remainder of the quarter decline by the same amount as the reference price, while their market shares in the second and third months of the quarter $s_{j,t'}^*$ remain unchanged. We abstract from punishment or other strategic responses in subsequent quarters because forming credible expectations about the longer-run evolution of prices and reference prices following a deviation is difficult.

A firm has deviation incentives if:

$$(P_{j,t}^* - c_{j,t}) \times s_{j,t}^* + \sum_{t'=2}^3 (P_{j,t'}^* - c_{j,t'}) \times s_{j,t'}^* < (\widehat{P}_{j,t} - c_{j,t}) \times \widehat{s}_{j,t} + \sum_{t'=2}^3 (\widehat{P}_{j,t'} - c_{j,t'}) \times s_{j,t'}^* \quad (7)$$

where P^* are the observed prices, s^* are the observed market shares, $\widehat{P}_{j,t} = \min_{k \neq j} \widehat{P}_{k,t} - \text{PriceBand} - \epsilon$ is the deviation price at the beginning of the quarter, $\widehat{s}_{j,t}$ is the expected market share in the first month given the deviation price $\widehat{P}_{j,t}$ and the expected prices of other firms $\widehat{P}_{k,t}$, $\widehat{P}_{j,t'}$ are the expected prices in the second and third months following the decrease in the reference price.

Table 5 reports, for products observed at the beginning of each quarter, whether our calculations suggest a profitable deviation and whether the product actually deviates in the data. The first panel, which pools all products, shows that 13.9% (sum of Columns 1 and 2, Panel 1) of products deviate, and 94% of them are profitable (13.0% in Column 2 divided by the sum of 13.9%). The remaining 86.1% of products (sum of Columns 3 and 4, Panel 1) do not deviate, even though 60% of them (51.5% in Column 4 divided by the sum of 86.1%) would have a profitable deviation.

In the second panel of firm types, the share of Big Six products classified as potential coordination is 58.2% (Panel 2, Row 1, Column 4) while that of other firms is 45.3% (Panel 2, Row 2, Column 4). This result is consistent with the descriptive analysis that the Big Six are more likely to follow the focal-pricing rule and less likely to undercut the previous reference price.

The third panel reports the results by market type. In Type 1 markets, Big Six firms have a higher share of suspected coordination of 57.4% (Panel 3, Row 1, Column 4) compared to 46.3% (Panel 3, Row 2, Column 4) of other firms. The suspected coordination share is highest in Type 3 markets (only Big Six) at 68.9% (Panel 3, Row 4, Column 4) compared to 41.1% (Panel 3, Row 3, Column 4) in Type 2 markets (only other firms). These patterns are consistent with the descriptive regression results that firms are more likely to succeed in having price-band-sized reference price increases when the market contains only the Big Six firms, or when the market has a large presence of the Big Six firms.

We next analyze the fourth panel to compare the three time periods. The share of products with a profitable deviation in the Learning Period of 2009-2012 is 45.6% (sum of Columns 2 and 4, Panel 4, Row 1). 20% of them actually deviate (9.3% in Column 2 divided by the sum of 45.6%).

In the Stable Period of 2013-2016, the share of products with a profitable deviation is 71.2% (sum of Columns 2 and 4, Panel 4, Row 2) compared to 45.6% in the previous period.

TABLE 5: OBSERVED DEVIATIONS AND PROFITABILITY OF DEVIATIONS

	Deviation		No Deviation	
	Not Profitable (1)	Profitable (2)	Not Profitable (3)	Profitable (4)
Panel 1: Overall	0.9%	13.0%	34.6%	51.5%
Panel 2: Firm Types				
Big 6	0.3%	5.1%	36.4%	58.2%
Other firms	1.4%	20.4%	32.9%	45.3%
Panel 3: Market Types				
Type 1 – Big 6	0.3%	5.1%	37.2%	57.4%
Type 1 – Non-Big 6	1.4%	18.6%	33.7%	46.3%
Type 2 – Non-Big 6	1.6%	28.2%	29.1%	41.1%
Type 3 – Big 6	0.5%	5.5%	25.2%	68.9%
Panel 4: Time Period				
2009-2012	1.4%	9.3%	53.0%	36.3%
2013-2016	0.8%	10.9%	28.1%	60.3%
2017-2020	0.6%	16.7%	27.4%	55.3%

Notes: Deviation: Observed price is more than the price band lower than rivals' prices at the end of the previous quarter. Profitable: Pricing at more than the the price band lower than rivals' prices at the end of the previous quarter is more profitable than keeping the price at the end of the previous quarter. Data source: Fimea (2009–2020).

Only 15% of them (compared to 20% in the previous period) actually deviate (10.9% in Column 2 divided by the sum of 71.2%). These results reflect two observations we have made in the previous sections. First, firms have stronger incentives to deviate in the Stable Period because the price level has increased substantially compared to the Learning Period. Second, firms deviate less often because they frequently follow the focal-point pricing rule during 2013-2016.

In the Post-2017-reform Period, the share of products with a profitable deviation is 72% (sum of Columns 2 and 4, Panel 4, Row 3). 23% of them (compared to 15% in the previous period) actually deviate (16.7% in Column 2 divided by the sum of 72%). This result indicates that firms deviate more often when the smaller price band is in place after 2017. Our calculations provide an intuitive explanation for this result. It is easier to undercut rivals sufficiently to push them above the reference price (and get the exclusive reimbursement and pharmacy recommendation status) when the price band is €0.5 than when it is €1.5 or €2.

6.4 Fixed-reference-price Prices

In this subsection, we focus on the fixed-reference-price periods during the remainder of the quarter — the second and third months of each quarter. We examine whether a fixed reference price prevents firms from pricing above it. Such an effect would provide evidence that the reference price system is effective in restricting prices. To achieve that goal, we ask the following questions: What if the full reimbursement and pharmacy recommendation status applied to all products instead of only those priced at or below the reference price? How would products currently priced at the reference price change their prices? We conduct two analyses. First, we ask whether these products would raise their prices above the reference price. Second, we ask whether they would raise their prices to the maximum price cap.

For the first analysis, we evaluate the derivative of a product's profit with respect to its own price, holding all rivals' prices fixed. If this derivative is positive for a product currently priced at the reference price, pricing at the reference price is a corner solution induced by the reference price regulation. In that case, the product would increase its price above the reference price if it retained its reimbursement and pharmacy recommendation status. The derivative is given by:

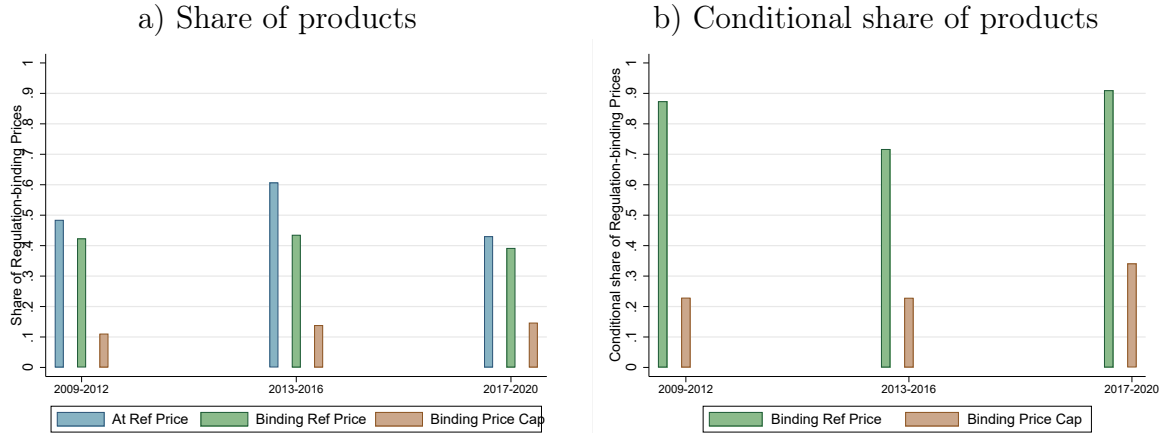
$$\frac{\partial \Pi_{jt}}{\partial P_{jt}} = s_{jt} + (P_{jt} - c_{jt}) \times \frac{\partial s_{jt}}{\partial P_{jt}} = s_{jt} + (P_{jt} - c_{jt}) \times \frac{(-\beta_1)s_{jt} \times (1 - s_{jt})}{P_{jt}} \quad (8)$$

For the second analysis, we also assume the rivals' prices fixed. We then change the price of a product currently priced at the reference price to the maximum price cap. After calculating the new market share and the new profit, we evaluate the derivative of the

product's new profit with respect to its new price. If this derivative is positive, the product would increase its price to the maximum price cap if it retained its reimbursement and pharmacy recommendation status.

Figure 10 examines whether the clustering of prices at the reference price in fixed-reference-price periods reflects a binding regulatory constraint. In the left graph, the blue bars show the shares of products priced exactly at the reference price. The green bars show the absolute shares (in the left graph) or the conditional shares (in the right graph) of products having a binding reference price. The orange bars show the absolute shares (in the left graph) or the conditional shares (in the right graph) of products having a binding maximum price cap. The left graph shows the share of products across different measures in three time periods. The right graph shows the share of products conditional on being priced exactly at the reference price.

FIGURE 10: FIXED-REFERENCE-PRICE PRICES



Notes: At Ref Price: Priced exactly at the reference price. Binding Ref Price: Priced exactly at the reference price because of corner solution. Binding Price Cap: Priced exactly at the reference price and would be priced at the maximum price cap in the absence of reference prices. Data source: Fimea (2009–2020).

In the left graph, in all three time periods, a substantial fraction of products are priced exactly at the reference price, with the share around 40-60 percent (blue bars in the left graph). Also in the left graph, the green and orange bars remain stable across the three time periods. Around 40% (left graph, green bars) of products are priced exactly at the reference price and have a binding reference price. They would charge higher than the reference price if they retained their reimbursement and pharmacy recommendation status. 10-15% (left graph, orange bars) of products are priced exactly at the reference price and have a binding maximum price cap. They would charge the maximum price cap if they retained its

reimbursement and pharmacy recommendation status. These results provide evidence that during the fixed-reference-price periods, the reference-price system is effective in restraining prices.

The difference between the three time periods is in the conditional shares in the right graph of Figure 10. In the Learning Period of 2009-2012, conditional on being priced at the reference price, 88% of products (right figure, first bar cluster, green bar) would price above it in the absence of the reference price. This number means that 88% of prices exactly at the reference price can be explained by competitive pricing subject to the reference price constraint. The remaining 12% of products are priced at the reference price even though competitive pricing predicts lower prices. We presume that these firms only price at the reference price within the quarter so that they could signal to others in the market that they would follow the focal-point pricing rule at the beginning of the next quarter.

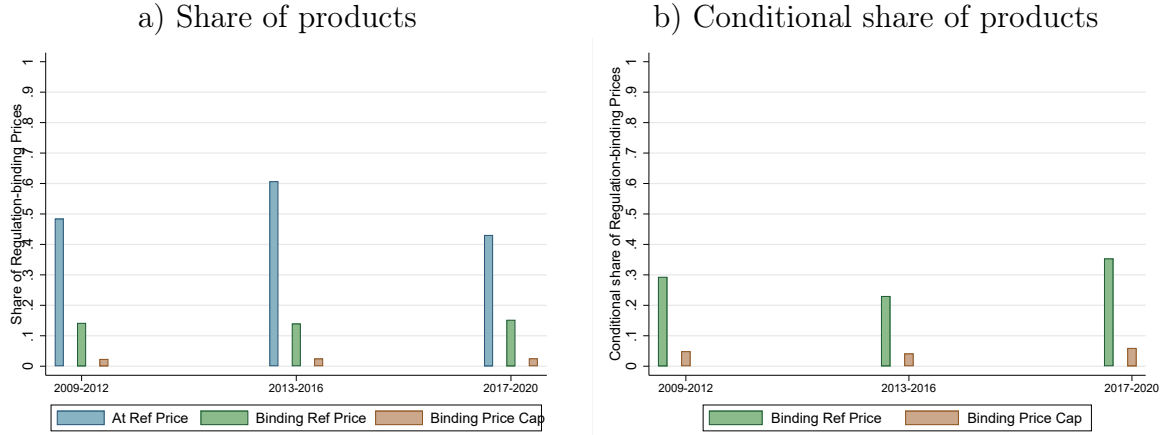
In the Stable Period of 2013-2016, the conditional share of products that are priced exactly at the reference price and have a binding reference price is only 71% (right figure, second bar cluster, green bar) compared to 88% in the previous time period. This result indicates that more products (29% compared to 12% previously) potentially try to signal their focal-point pricing behavior during the remainder of the quarter.

In the Post-2017-reform Period, the conditional share of products that are both priced exactly at the reference price and having a binding reference price increases to 91% (right figure, third bar cluster, green bar). A smaller share of firms (9%) potentially trying to signal their focal-point pricing behavior is consistent with our descriptive analysis that the focal-point pricing behavior becomes less prevalent after the reduction of the price band in 2017.

To assess the sensitivity of our conclusions to our marginal cost assumption, we repeat the exercise under the extreme assumption that marginal costs are zero and report the results in Figure 11. Conditional on being priced at the reference price, 23-35% (right graph, green bars) of products would want to price higher if they retained their reimbursement and pharmacy recommendation status. Conditional on being priced at the reference price, around 5% (right graph, orange bars) of products would prefer to increase their price to the maximum price cap if they retained their reimbursement and pharmacy recommendation status.

The two marginal-cost assumptions provide a range for the significance of the reference-price constraint. If true marginal costs lie between zero and our minimum-observed-price marginal costs, our calculations imply that between 23 and 91 percent of products are priced at the reference price because the reference price is binding. Also, between 5 and 32 percent of products at the reference price would prefer to charge the regulated price cap without

FIGURE 11: FIXED-REFERENCE-PRICE PRICES - ZERO MCs



Notes: At Ref Price: Priced exactly at the reference price. Binding Ref Price: Priced exactly at the reference price because of corner solution. Binding Price Cap: Priced exactly at the reference price and would be priced at the maximum price cap in the absence of reference prices. Data source: Fimea (2009–2020).

the reference-price regulation. Even under the extreme assumption of zero marginal costs, the results indicate that the reference price is binding for many products. Our calculations therefore suggest that on the positive side, the reference price constrains firms from increasing prices further in the fixed-reference-price periods.

7 Conclusion

We find that firms frequently match the previous quarter’s reference price, leading to systematic increases in prices that are equal to the price band in the Finnish pharmaceutical market. This pattern suggests that price regulation, while restraining prices, may also provide a mechanism for firms to coordinate their prices without explicit communication. Understanding the interaction between regulation and strategic firm behaviors is crucial for improving reference price systems and price regulation in general.

We have documented a tug-of-war game between the regulator and firms in the Finnish pharmaceutical market. In 2009, the regulator introduced the reference price system that facilitated price competition among firms and led to a substantial drop in prices. However, firms gradually learned to utilize the reference price as a tool for tacit coordination through the focal-point pricing behavior. They succeeded in increasing prices during 2012–2016. In 2017, the regulator reduced the price band from €1.5/€2 to €0.5 following a government proposal. The proposal acknowledged that prices had been increasing in some markets, and

the main goal was to increase price competition (Government of Finland, 2016), but it did not identify the focal-point pricing pattern we documented. By the end of our sample in 2022, the reduction in the price band had resulted in lower prices. The focal-point pricing behavior remained present, but at a lower frequency. It remains to be seen how firms continue to adapt to the regulation after 2022.

We provide descriptive evidence that a larger price band before 2017 has negative consequences because it determines the size of reference price increases in many markets with focal-point coordination. We also document a decline in the focal-point pricing behavior at the product level and also price-band-sized reference-price increases at the market level after the price band reduction in 2017. Our structural model offers an intuitive explanation for the effectiveness of a smaller price band. It is easier to undercut rivals sufficiently to push them above the reference price (and get the exclusive reimbursement and pharmacy recommendation status) when the price band is €0.5 than when it is €1.5 or €2.

Our analysis of prices during the fixed-reference-price periods suggests that, after the reference price is fixed, it restrains many firms from pricing above it. Therefore, having the reference price fixed for the entire quarter prevents firms from raising prices further and faster. Furthermore, another reason for fixing the reference price for the whole quarter is to maintain demand predictability for pharmaceutical firms, wholesalers, and pharmacies. Without sufficient predictability, manufacturing, importing, and managing inventories would become more difficult (Government of Finland, 2002).

Based on our results, we recommend a further reduction in the price band while keeping the reference price fixed for the whole quarter. Our policy recommendation is based on the observed market structures and the prevalence of the focal-point pricing behavior in our data. If the Finnish pharmaceutical market attracts more competitive entrants that do not follow the focal-point pricing behavior, as described in Appendix Section A-2 for a minority of markets, more frequent reference price adjustments could lead to greater price reductions by giving firms more opportunities to undercut one another.

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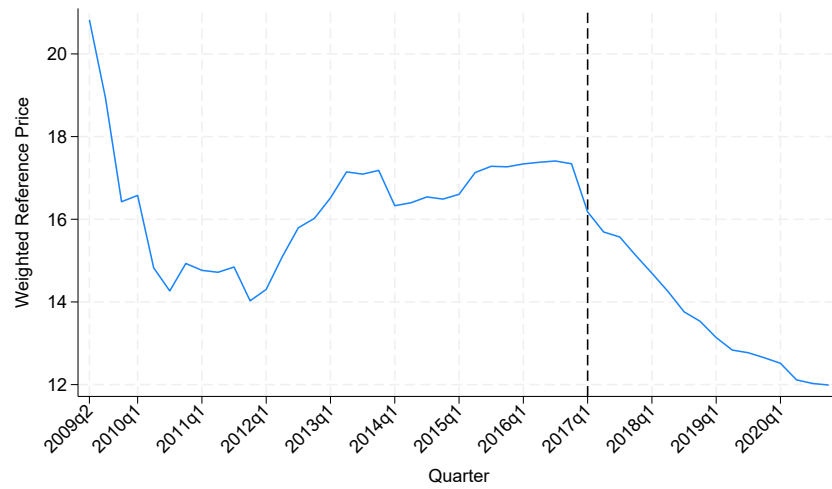
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Appendix

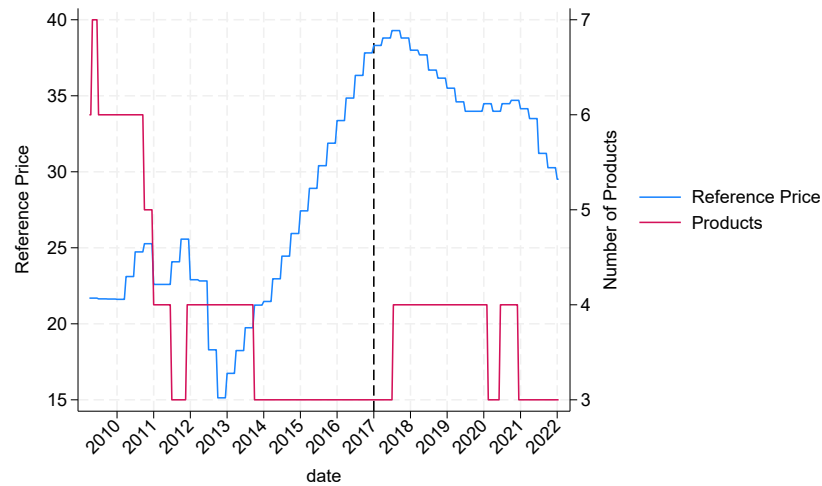
A-1 Descriptive Statistics

FIGURE A-1: AVERAGE REFERENCE PRICE



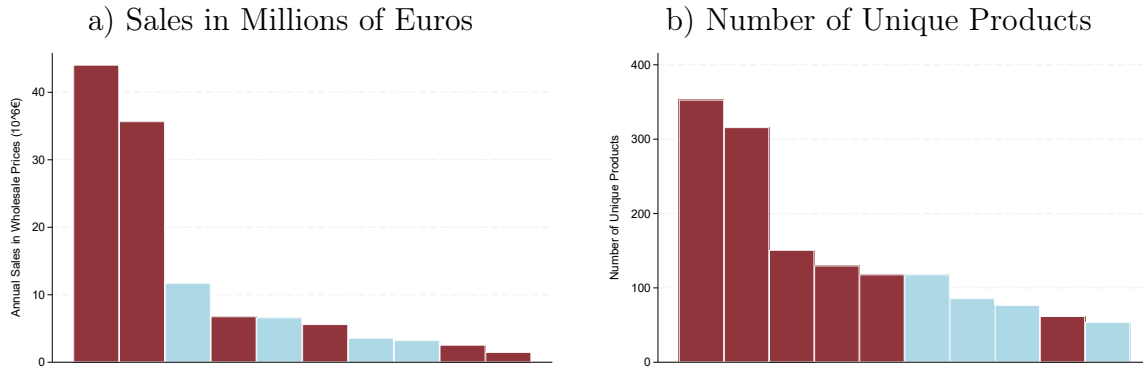
Notes: Weighted by sales in 2016q4. Data source: AFP (2009—2022), Hila (2009–2022), Fimea (2009–2020).

FIGURE A-2: PRICES IN A REFERENCE PRICE GROUP



Notes: Data source: AFP (2009–2022).

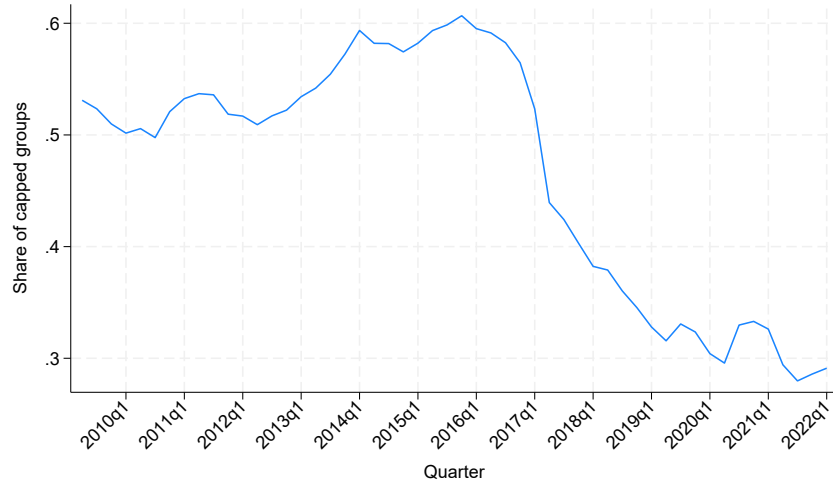
FIGURE A-3: FIRM-LEVEL ANNUAL SALES AND NUMBER OF PRODUCTS IN 2009 - TOP 10



Both figures include the top 10 prominently generic producing pharmaceutical companies in terms of sales or the number of products in the Finnish reference price system. Maroon bars signify the Big Six, blue bars signify other pharmaceutical companies in the top 10. Figure a) represents the annual sales of the Big Six and others in wholesale prices over all products that belong to the reference price system. Figure b) represents the annual number of unique product numbers. Data Source: AFP (2009), Fimea (2009).

Figure A-4 shows that the share of reference price groups constrained by price caps increased between 2012 and 2016 before subsequently declining.

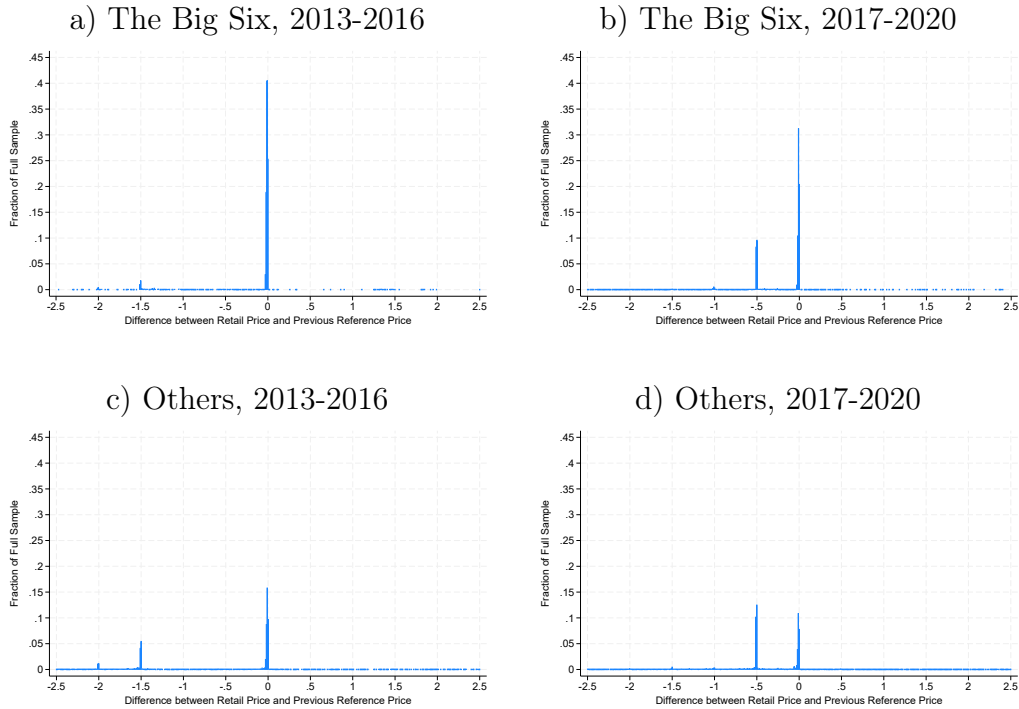
FIGURE A-4: PRICE CAPPED GROUPS



Share of reference price groups in which an increase equal to the width of the price band is prevented by the price caps. Data source: AFP (2009–2022).

Figure A-5 documents a pronounced difference between the auction bids of the Big Six and those of other firms. The figure plots the difference between a product's auction price and the previous quarter's reference price. A price difference of zero therefore corresponds to the

FIGURE A-5: RETAIL PRICE DIFFERENCES FROM THE PREVIOUS QUARTER'S
REFERENCE PRICE



Notes: Difference between retail prices and the previous quarter's reference price at the beginning of a quarter. Observations are on quarter $\times$ product number level. The bars signify the share out of all observations that match the firm and timing criteria. Bin width is 0.01€. We report differences between -2.5€ and 2.5€ for the sake of clarity. We exclude observations for which the reference price exceeds the lowest price cap within a reference price group. We exclude quarter 1 of 2013 because a VAT reform shifts retail prices mechanically. We exclude quarter 1 of 2014 because pharmacy markup reform shifts retail prices mechanically. Data source: AFP (2009—2022), Hila (2009—2022)

focal-pricing rule: the firm submits a bid exactly equal to the previous reference price. This pricing rule has an important implication for the evolution of the reference price. Because the new reference price is determined by the lowest submitted price plus the applicable price band, if all products bid at the previous reference price, the new reference price increases by exactly the price band. In contrast, a single sufficiently low bid can prevent this increase or even reduce the reference price. In particular, for the new reference price to fall below the previous reference price, at least one product must submit a bid more than the applicable price band below the previous reference price, corresponding to a price difference below -0.5 , -1.5 , or -2 euros depending on the price-band rule applying to that market.

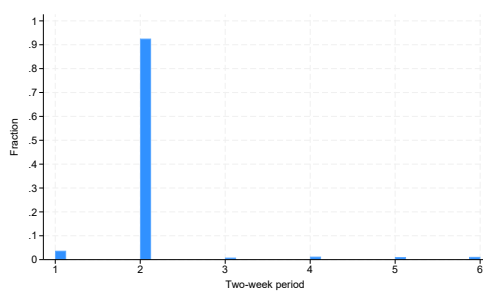
TABLE A-1: PRICE-BAND-SIZED REFERENCE PRICE INCREASES OVER ATC1s

	ATC1													
	A	B	C	D	G	H	J	L	M	N	P	R	S	V
Observations	3793	312	10642	1263	1295	556	5332	2364	2777	13131	103	1523	503	28
RP PB Increase Share	0.09	0.05	0.09	0.10	0.15	0.03	0.10	0.11	0.06	0.10	0.03	0.07	0.05	0.21
Obs Excl. Capped	2554	291	6790	653	937	254	2631	1880	1542	8728	12	1000	287	28
RP PB Increase Share	0.13	0.05	0.14	0.19	0.20	0.06	0.20	0.14	0.11	0.15	0.25	0.11	0.09	0.21

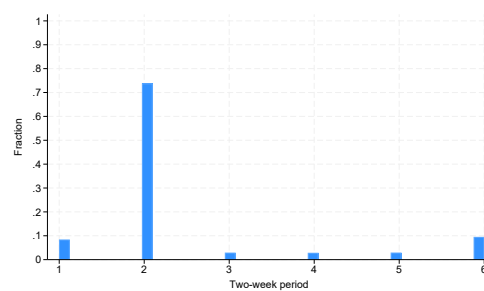
Notes: The unit of observation is a reference-price-group-by-quarter. The table reports, by ATC1 category, the total number of observations (*Observations*); the share of observations experiencing a reference-price increase equal to the width of the applicable price band (*RP PB Increase Share*); the number of observations for which the reference price was not constrained by the price cap in the preceding quarter (*Obs. Excl. Capped*); and the corresponding share of price-band-sized reference-price increases among these unconstrained observations (*RP PB Increase Share, Excl. Capped*). Data source: AFP (2009–2022), Hila (2009–2022).

FIGURE A-6: DISTRIBUTION OF PRICE CHANGE TIMINGS

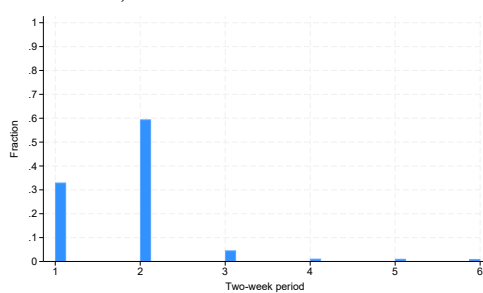
a) The Big Six, 2013-2016



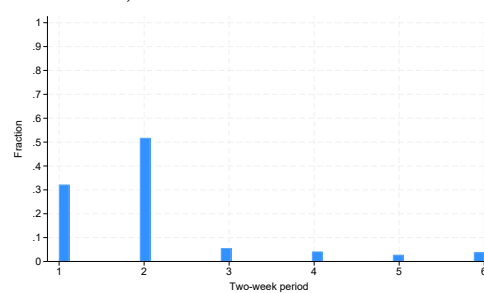
b) The Big Six, 2017-2020



c) Others, 2013-2016

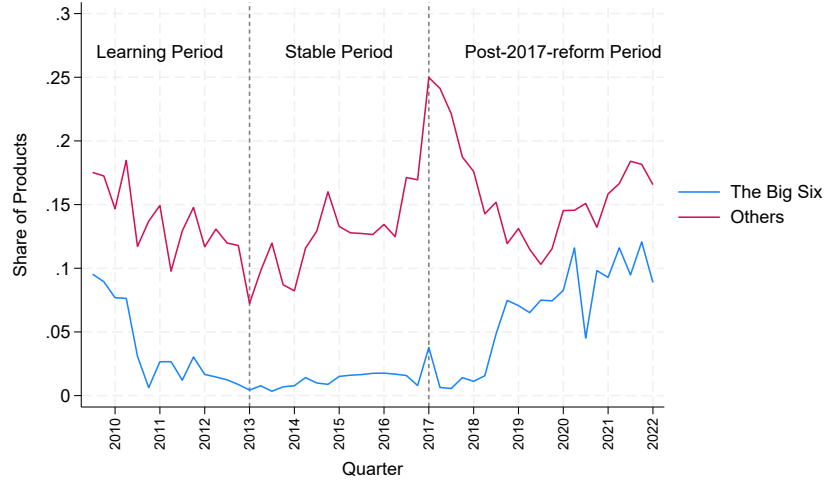


d) Others, 2017-2020



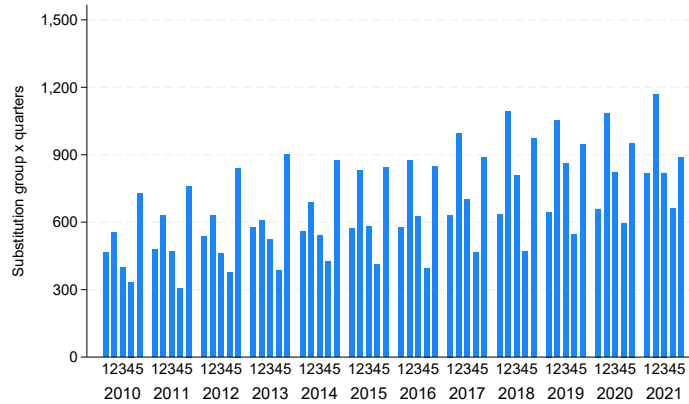
Notes: Distribution of wholesale price changes over two-week periods for the Big Six and others before and after 2017. Data source: AFP (2013—2020).

FIGURE A-7: UNDERCUT DECISIONS



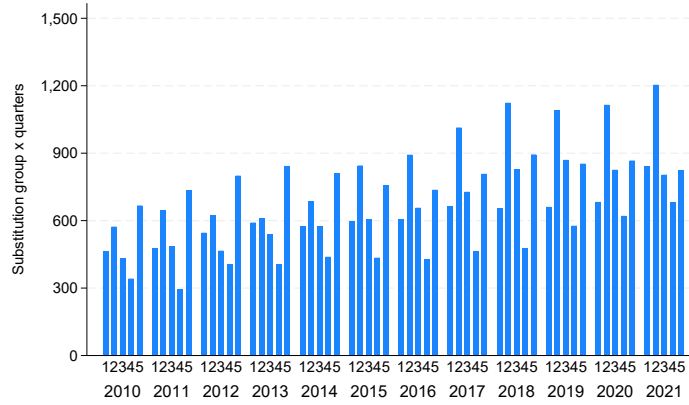
Notes: Share of products at the beginning of a quarter that are priced in a way that would leave all other products outside the price corridor if the other products kept two-week period 6 prices from the previous quarter. Share of products in 2014Q1 is adjusted to take into account the pharmacy markup reform. Products that do not affect the reference price setting process in a given quarter are excluded. Data source: AFP (2009–2022), Hila (2009–2022).

FIGURE A-8: PRODUCTS IN A REFERENCE PRICE GROUP EXCLUDING THE BIG SIX



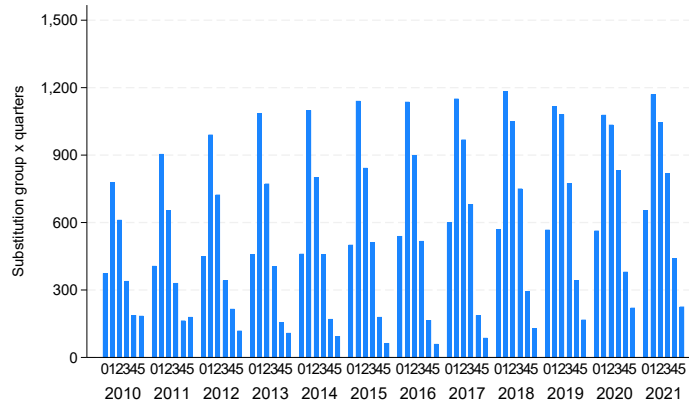
Number of products in a reference price group. All other bins represent the exact number of products except bin 5. In bin 5, we have pooled all reference price group $\times$ quarter observations that include five or more products. Data source: AFP (2010–2021).

FIGURE A-9: MARKET AUTHORIZATION HOLDERS IN A REFERENCE PRICE GROUP



Number of market authorization holders in a reference price group. All other bins represent the exact number of market authorization holders except bin 5. In bin 5, we have pooled all reference price group $\times$ quarter observations that include five or more market authorization holders. Data source: AFP (2010–2021).

FIGURE A-10: MARKET AUTHORIZATION HOLDERS IN A REFERENCE PRICE GROUP EXCLUDING THE BIG SIX

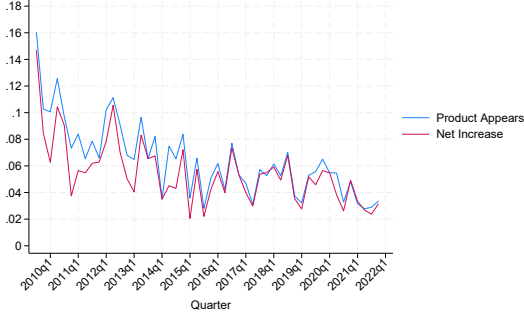


Number of market authorization holders in a reference price group. All other bins represent the exact number of market authorization holders except bin 5. In bin 5, we have pooled all reference price group $\times$ quarter observations that include five or more market authorization holders that are not part of the Big Six. Data source: AFP (2010–2021).

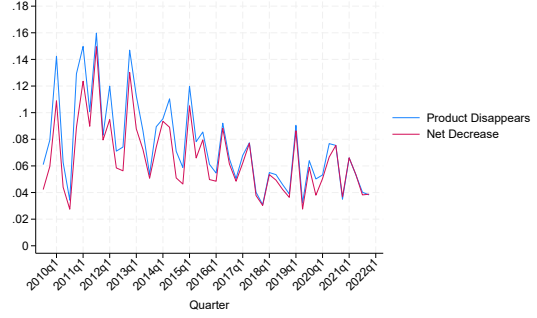
A-2 Entry and Exit

FIGURE A-11: ENTRY AND EXIT PATTERNS

a) Entry



b) Exit



Notes: Share of reference price groups in which an entry or exit occurs. We do not consider formation or removal of entire reference price groups as entry or exit. Data source: AFP (2009–2022), Hila (2009–2022)

Figure A-11 shows entry and exit patterns within the reference price system. The blue line in Figure A-11a represents the quarterly share of reference price groups in which a product number was observed even though it was not observed at the beginning of the previous quarter. Conversely, in Figure A-11b, it represents the quarterly share of reference price groups in which a product number was not observed even though it was observed at the beginning of the previous quarter. The red line describes the share of reference price groups in which there is a net increase in Figure A-11a, or a net decrease in Figure A-11b, in the number of observed product numbers from the previous quarter.

The blue line can be interpreted as an upper bound when we consider entry and exit strictly to and from the reference price system. If a product's product number changes due to a change in e.g., the ownership of the product, the blue line counts it as both an entry and an exit. The red line responds only to changes in the aggregate number of products, acting as an effective lower bound for entry and exit decisions. Despite these differences in the definitions, the lines follow each other closely.

Figure A-11 shows that both entry and exit are high and volatile during the initial learning phase before 2013. Reference price groups experiencing entry range from 4% to 16% per quarter. During the same period, groups facing exits vary between 3% and 16% quarterly. Given the intensity of exits particularly before 2013, the changes in market structure and decreased competition may have further incentivized those firms who stayed in the market to price their products according to the focal pricing rule. Afterwards, the share of reference price groups having entrants varies between 2% and 10% each quarter. The corresponding shares for exits are 3% and 12%.

Table A-2 reports OLS regression results for the following specification:

$$\begin{aligned}
 \mathbb{1}\{RP_{mt} < RP_{mt-1}\} = & \beta_0^M + \beta_1^M \times \text{Entry}_{mt} + \beta_2^M \times \mathbb{1}\{\text{Year}_{mt} \geq 2017\} \\
 & + \beta_3^M \times \mathbb{1}\{\text{Year}_{mt} < 2013\} + \beta_4^M \times \mathbb{1}\{\text{Entry}_{mt}\} \times \mathbb{1}\{\text{Year}_{mt} \geq 2017\} \\
 & + \beta_5^M \times \mathbb{1}\{\text{Entry}_{mt}\} \times \mathbb{1}\{\text{Year}_{mt} < 2013\} + \lambda_m^M + \lambda_t^M + \epsilon_{mt}^M
 \end{aligned} \tag{A-1}$$

That is, we regress a dummy indicating a decrease in the reference price on one of our entry measures in Figure A-11 (Entry_{mt}) in reference price group m and quarter t , a dummy indicating Post 2017 time period ($\mathbb{1}\{\text{Year}_{mt} \geq 2017\}$), a dummy indicating Pre 2013 time period ($\mathbb{1}\{\text{Year}_{mt} < 2013\}$), their interactions, reference price group fixed effects (λ_m^M) in columns 2, 3, 5, and 6, and quarter (λ_t^M) fixed effects in columns 3 and 6. The data is on reference price group and quarter level. We focus on 2009Q3–2020Q4.

In all of the descriptive regressions of Table A-2, entry is positively associated with a decrease in the reference price that quarter regardless of whether we measure it as new product numbers we did not observe at the beginning of last quarter in columns 1–3 or an increase in the aggregate number of products in columns 4–6. The linear probability model predicts an increase of 31 percentage points in the probability of reference price decrease when we do not include reference price group or quarter fixed effects. Once we include these fixed effects and focus on within-group variation, the increase the coefficient implies falls to 16 percentage points. In addition, both before 2013 and after 2017, entry is even more strongly associated with a decrease in the reference price. After 2017, there is a 7–9 percentage point increase in the probability of the reference price decreasing when a new product enters. The result is consistent with hypotheses such as there being a behavioral change or the identity of entrants changing. Similarly, a 7–9 percentage point increase in the probability of the reference price decreasing before 2013 highlights the initial learning phase and potential differing composition of entrants.

Next, we shift attention to individual products and companies. Table A-3 reports OLS estimates using product-quarter level data for 2009Q3–2020Q4. We estimate the following specification:

$$\begin{aligned}
 \mathbb{1}\{P_{jmt} < RP_{mt-1} - \text{PriceBand}_{mt}\} = & \beta_0^J + \beta_1^J \times \text{Entrant}_{jmt} \\
 & + \beta_2^J \times \mathbb{1}\{\text{Year}_{jmt} \geq 2017\} + \beta_3^J \times \mathbb{1}\{\text{Year}_{jmt} < 2013\} \\
 & + \beta_4^J \times \text{Entrant}_{jmt} \times \mathbb{1}\{\text{Year}_{jmt} \geq 2017\} \\
 & + \beta_5^J \times \text{Entrant}_{jmt} \times \mathbb{1}\{\text{Year}_{jmt} < 2013\} + \epsilon_{jmt}^J
 \end{aligned} \tag{A-2}$$

The dependent variable is an indicator equal to one if product j in reference price group m sets a price in quarter t low enough to reduce the reference price from the previous quarter. Entrant_{jmt} , indicates whether the product is an entrant. We interact this entrant dummy with dummies for the post-2017 period and the pre-2013 period. Column (1) reports the baseline specification, column (2) adds reference price group fixed effects, and column (3) adds product fixed effects.

These descriptive results indicate that entrants are more likely than incumbents to price below the threshold required to reduce the reference price. In columns (1) and (2), this

TABLE A-2: ENTRY, PRODUCT EXPANSION, AND REFERENCE PRICE DECREASES

	Entry			Net Increase in Products		
	(1) RP ↓	(2) RP ↓	(3) RP ↓	(4) RP ↓	(5) RP ↓	(6) RP ↓
Entry	0.307*** (0.021)	0.159*** (0.018)	0.155*** (0.018)			
Post 2017	0.147*** (0.010)	0.103*** (0.011)		0.148*** (0.010)	0.104*** (0.011)	
Entry × Post 2017	0.070** (0.028)	0.085*** (0.025)	0.084*** (0.025)			
Pre 2013	0.035*** (0.010)	0.097*** (0.010)		0.039*** (0.010)	0.099*** (0.010)	
Entry × Pre 2013	0.088*** (0.026)	0.088*** (0.025)	0.070*** (0.024)			
Net Increase in Products				0.364*** (0.022)	0.204*** (0.019)	0.198*** (0.019)
Net Increase in Products × Post 2017				0.025 (0.030)	0.054** (0.027)	0.056** (0.027)
Net Increase in Products × Pre 2013				0.079*** (0.029)	0.085*** (0.028)	0.068** (0.027)
Constant	0.165*** (0.008)	0.176*** (0.006)	0.242*** (0.001)	0.165*** (0.008)	0.176*** (0.006)	0.242*** (0.001)
Substitution-group FE	No	Yes	Yes	No	Yes	Yes
Quarter FE	No	No	Yes	No	No	Yes
Observations	35,200	35,172	35,172	35,200	35,172	35,172
R-squared	0.064	0.296	0.352	0.066	0.298	0.354

Standard errors in parentheses

Dependent variable is an indicator for a decrease in the reference price. Standard errors are clustered at the reference price group level. Base levels and omitted variables are not reported.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

tendency is particularly prominent after 2017. However, when we include product fixed effects in column (3), the entrant $\times$ post-2017 interaction decreases and becomes statistically insignificant. This suggests that the stronger post-2017 association may partly reflect changes in the composition of entrants rather than changes in the behavior of the same products over time.

The entrant $\times$ pre-2013 interaction shows the opposite pattern. It is small and statistically insignificant in columns (1) and (2), but becomes positive and statistically significant after adding product fixed effects in column (3). This is consistent with behavioral differences among entrants between the initial learning phase in 2009–2012 and the main focal-pricing period in 2013–2016.

TABLE A-3: ENTRY AND REFERENCE-PRICE UNDERCUTTING

	(1) Undercut	(2) Undercut	(3) Undercut
Entrant	0.215*** (0.015)	0.198*** (0.014)	0.116*** (0.013)
Post 2017	0.097*** (0.005)	0.084*** (0.005)	0.057*** (0.005)
Entrant $\times$ Post 2017	0.133*** (0.023)	0.119*** (0.021)	0.008 (0.021)
Pre 2013	0.026*** (0.004)	0.037*** (0.004)	0.030*** (0.003)
Entrant $\times$ Pre 2013	0.009 (0.021)	0.008 (0.021)	0.047** (0.019)
Constant	0.065*** (0.003)	0.067*** (0.002)	0.081*** (0.002)
Substitution-group FE	No	Yes	No
Product FE	No	No	Yes
Observations	124,442	124,436	124,239
R-squared	0.033	0.085	0.371

Standard errors in parentheses

Dependent variable is an indicator for pricing sufficiently below the previous reference price to reduce the new reference price. Standard errors clustered at the reference price group level.

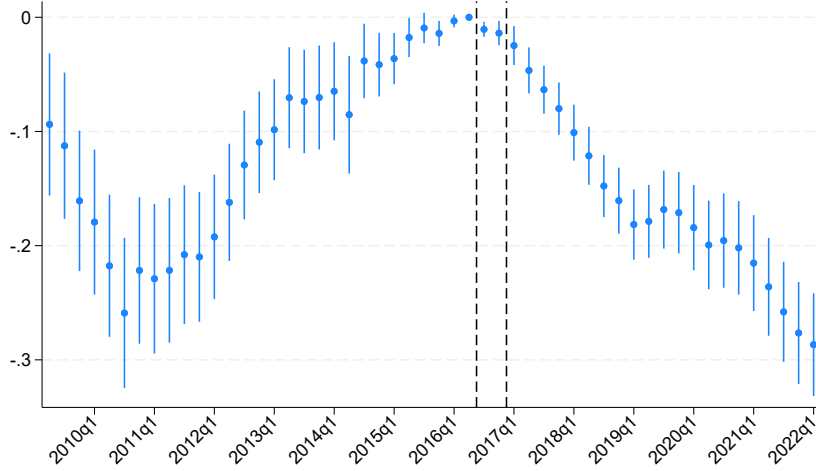
Omitted and base categories are not reported.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A-3 Reduced Form

A-3.1 Without Control Group

FIGURE A-12: QUARTER FES OF REFERENCE PRICES REGRESSION



Estimated quarter fixed effects from a regression in which the dependent variable is the logarithm of the reference price, excluding pharmacy margins and VAT. The unit of observation is a reference-price-group-by-quarter. Standard errors are clustered at the reference-price-group level. The sample includes all reference price groups from 2009Q2 through 2022Q1. Data source: AFP (2009—2022), Hila (2009–2022).

A-3.2 Event Studies on Market-level Outcomes

We estimate event studies at the active-ingredient level using average pharmaceutical expenditure per defined daily dose (DDD) and the number of distinct firm names as the outcomes. Norwegian corresponding active ingredients form the control group. We aggregate outcomes at market-level rather than at the product-level because the price of one product may affect the prices of competing products in the same market. A product-level analysis could violate the Stable Unit Treatment Value Assumption (SUTVA) through interference across products. Following Kortelainen et al. (2023), we define markets on active ingredient level rather than reference price group level. A broader market definition should further alleviate concerns regarding SUTVA although it may dilute the estimated effect due to inclusion of products that are less directly affected by the reform. In addition, because reference price groups are specific for the Finnish institutional setting, mapping across countries is more clean on a broader, active ingredient, level.

Following Kortelainen et al. (2023) and Markkanen et al. (2026), we construct average expenditure by dividing nominal wholesale sales by the number of defined daily doses sold at the active ingredient level and then taking the logarithm of this variable. We calculate the number of firms based on distinctly named firms within a market.

We construct the control group using the same active ingredients observed in Norway. Because all Finnish reference price groups face the price band reform, there are no plausible within-country control groups. We consider Norway a plausible control country because pharmaceutical market conditions and expenditure trends appear reasonably comparable to those in Finland during the pre-reform period. [Markkanen et al. \(2026\)](#), for example, document broadly similar effects of loss of exclusivity on average expenditure in Finland and Norway during the early and mid-2010s. Norway also regulates prices with two maximum price controls. The first price control mechanism is based on the mean price in three countries where the prices of the corresponding products are the lowest among a basket of nine European countries ([Weise et al., 2018](#)). Therefore, Norwegian prices, at least when bound by the price cap, should reflect changes in European price trends. Norway also uses a stepped price model which imposes predetermined price cuts soon after the product begins to face generic competition ([Weise et al., 2018](#)). We do not consider this part of the regulation as a notable issue for identification because it is mainly targeted for products that have recently lost patent protection and most markets in our sample have been under generic competition for quite a while already.

Some markets affected by the 2017 price band reform were also affected by another reform in July 2016. The price caps of some of the branded and parallel imported pharmaceuticals were adjusted to the same level as the price caps of generics in the same reference price group. Whether this reform affected a market was dependent on whether such products were present in the Finnish pharmaceutical market at the time. Because entry and exit decisions are endogenous, selection into exposure to the price cap reform is a concern. Therefore, an event study setting does not allow us to conclusively separate the effects of the price cap reform and the price band reform for those markets that faced both treatments. In addition due to selection, we cannot rule out, and likely should expect, that the price band reform affects differently those markets that faced the price cap reform and those that did not.

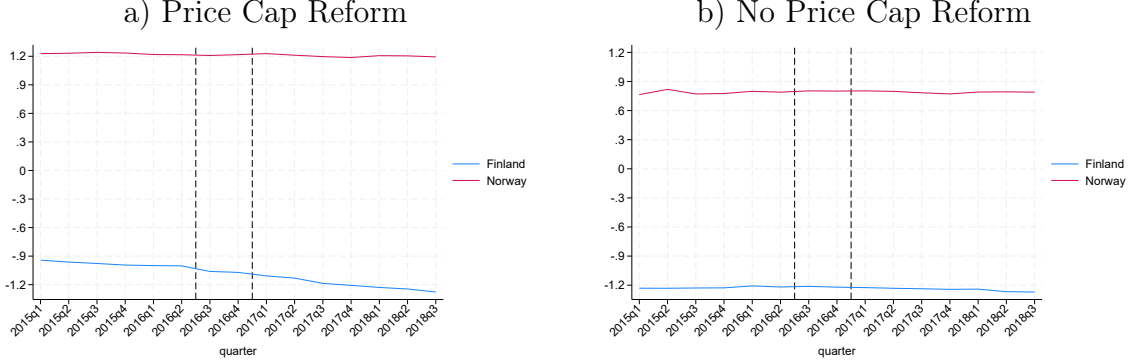
Our parallel trends assumption is that without the reforms, the logarithmic market-level outcomes in Finland would have developed with similar trends as their Norwegian counterparts. Because the treatments and their timings are different for those markets that faced the price cap reform and those that did not, the former being affected by the price cap reform after July 2016 and by both price cap and price band reforms after January 2017, we estimate two separate event studies. We set the baseline period to quarter two of 2016 for the markets that were affected by the price cap reform and quarter four of 2016 for those that were not because these were the last quarters before the respective reforms.

We restrict the sample to the period from 2015 through the third quarter of 2018 and aggregate the data at the active-ingredient-by-country-by-quarter level. We use a balanced sample of active ingredients so that we observe sales from each active ingredient in both countries through the whole sample period to avoid compositional changes. However, this restriction rules out, for example, smaller markets due to us restricting the markets only to those that have positive sales each quarter.

We plot raw means of the outcome variables for Finland and Norway separately for the active ingredients that faced the price cap reform and those that did not in [Figures A-13 and A-14](#). The level differences between countries are expected by design in [Figure A-13](#) because we measure average expenditure per DDD in local nominal currency. There are also level differences between the two market groups — those markets that faced the price cap reform

had higher average expenditure in both countries before the treatment. However, at the end of our sample period, average expenditure converges in Finland between these two groups.

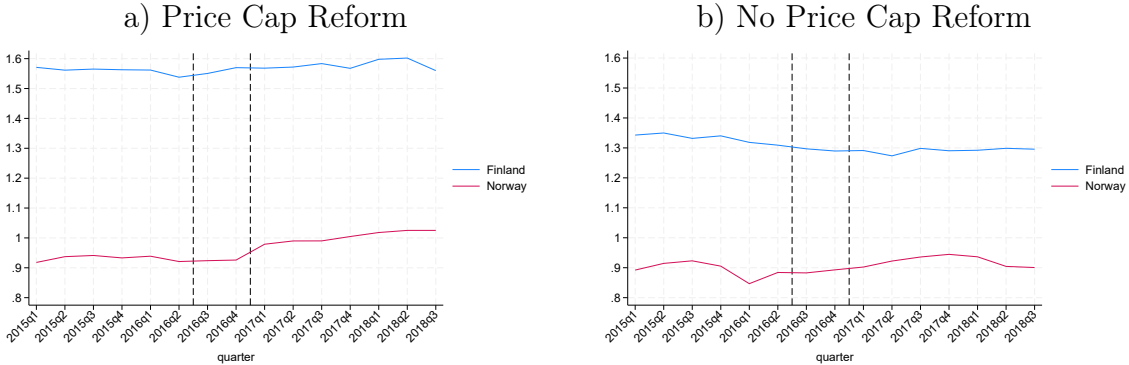
FIGURE A-13: LOGARITHMIC AVERAGE EXPENDITURE MEANS



Unweighted mean of logarithmic average expenditure per DDD over markets in Finland and Norway. The balanced sample contains 63 distinct active ingredients observed in both countries in panel a) and 85 in panel b).

Figure A-14 shows level differences in the number of firms. Finland has more firms per market on average compared to Norway. In addition, markets in Finland that are affected by the price cap reform have more firms than those which do not. Changes in the mean of number of firms are modest in both countries. The number of firms increases slightly in Norway in the post-treatment period, at least relative to 2016 levels.

FIGURE A-14: LOGARITHMIC NUMBER OF FIRMS MEANS



Unweighted mean of logarithmic number of firms over markets in Finland and Norway. The balanced sample contains 63 distinct active ingredients observed in both countries in panel a) and 85 in panel b).

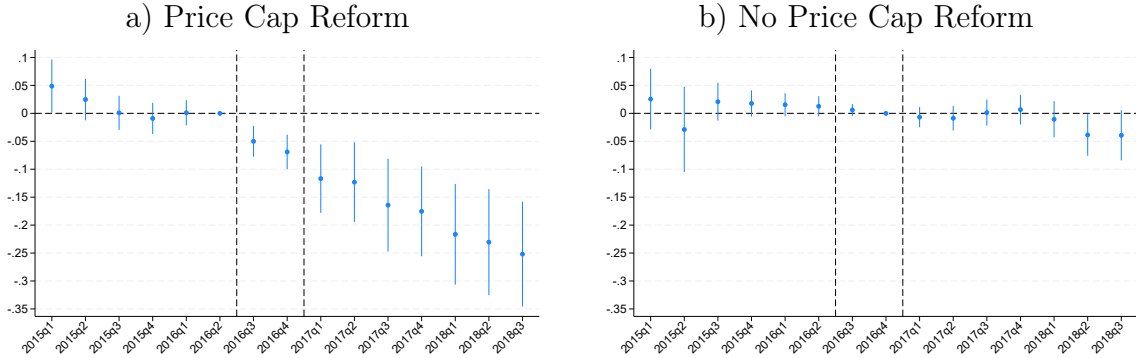
Our estimation equation is as follows:

$$\ln(y_{mct}^{DID}) = \alpha^{DID} + \sum_{k \neq k_0} \beta_k^{DID} [\mathbf{1}\{c = \text{Finland}\} \times \mathbf{1}\{t = k\}] + \lambda_t^{DID} + \lambda_{mc}^{DID} + \varepsilon_{mct}^{DID}, \quad (\text{A-3})$$

in which y_{tmc}^{DID} denotes the outcome variable in quarter t , market m , and country c . The

term α^{DID} is a constant, $\mathbf{1}\{c = \text{Finland}\}$ is an indicator for the treated country, and $\mathbf{1}\{t = k\}$ is an indicator for quarter t . The parameters λ_t^{DID} and λ_{mc}^{DID} denote quarter fixed effects and market-by-country fixed effects, respectively. ϵ_{tmc}^{DID} is the error term. The coefficients β_t^{DID} capture the evolution of the treatment effect over time. We estimate the specification using a two-way fixed-effects estimator. We cluster standard errors on active ingredient level and assign the same weight to all active ingredient.

FIGURE A-15: EVENT STUDY ON LOGARITHMIC AVERAGE EXPENDITURE



The dependent variable is the logarithm of the average expenditure per DDD. The unit of observation is an active-ingredient-by-country-by-quarter. Finland constitutes the treatment group, and Norway the control group. Observations are matched across countries and periods by active ingredient. Standard errors are clustered at the active-ingredient level. The balanced sample contains 63 distinct active ingredients observed in both countries in panel a) and 85 in panel b). Data sources: Fimea (2015–2018), Farmastat (2015–2018), and AFP (2015–2018).

Figure A-15 reports the estimated effects on average expenditure per DDD, β_t^{DID} . In both panels, the pre-treatment coefficients are generally statistically insignificant and close to zero. The estimated average effect on the treated (ATT) of the price cap reform on average expenditure per DDD is -7% ⁷ by 2016Q4 under the assumption that there is no anticipation due to the price band reform. The following joint effect of the price cap and price band reforms develops gradually from -11% in 2017Q1 to -22% in 2018Q3.

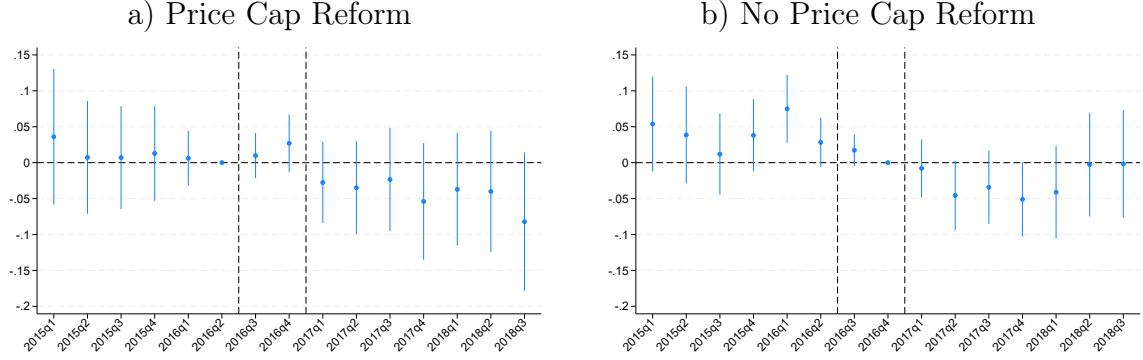
While the effects are not directly separable in this setting, we can form an upper bound for the decrease in average expenditure per DDD due to the price band reform under additional assumptions. If we assume that the effect of the price cap reform does not become less negative and, absent the price cap reform's effect, the rest of the effect can be attributed to the price band reform, the estimated ATT due to the price band reform would be at most -16% by the end of our sample period. Given the trend in the joint effect and our descriptive results, such as Figures 1 and A-1, it is also not clear that the average expenditure per DDD decreasing trend would stop here if we had data from the control group for a longer period.

Figure A-15b) shows that the estimated ATT of the price band reform on average expenditure per DDD for the group that did not face the price cap reform is close to zero. The point estimates indicate a decrease of at most -4% by the end of our sample period. This

⁷Under the assumption that the error terms are normally distributed and homoskedastic, we transform our estimated coefficients to percentages $(e^{\beta_k^{DID}} - 1) \times 100\%$.

difference between the treatment groups may be indicative of smaller than expected effects of the price band reform on average expenditure per DDD although we find the hypothesis on selection-induced heterogeneous responses a plausible alternative.

FIGURE A-16: EVENT STUDY ON LOGARITHMIC NUMBER OF FIRMS



The dependent variable is the logarithm of the number of firms. The unit of observation is an active-ingredient-by-country-by-quarter. Finland constitutes the treatment group, and Norway the control group. Observations are matched across countries and periods by active ingredient. Standard errors are clustered at the active-ingredient level. The balanced sample contains 63 distinct active ingredients observed in both countries in panel a) and 85 in panel b). Data sources: Fimea (2015–2018), Farmastat (2015–2018), and AFP (2015–2018).

Figure A-16 reports the estimated effects on the number of firms per market. The coefficients are statistically insignificant and close to zero for the most part both before the treatments and after them. Thus, they suggest that the reduction in average expenditure is not associated with an increase in the aggregate number of firms operating in the market. However, this finding does not rule out the possibility that changes in the composition of the entrants are a plausible mechanism which drives average expenditure and price decreases. If firms pricing their products more aggressively replace incumbents, as potentially suggested by Section A-2, the market-level prices and average expenditure are expected to decrease.

A-4 Back-of-the-envelope calculations - Change of the price band size

A-4.1 Back-of-the-envelope calculation 1 - €0.50 price band size

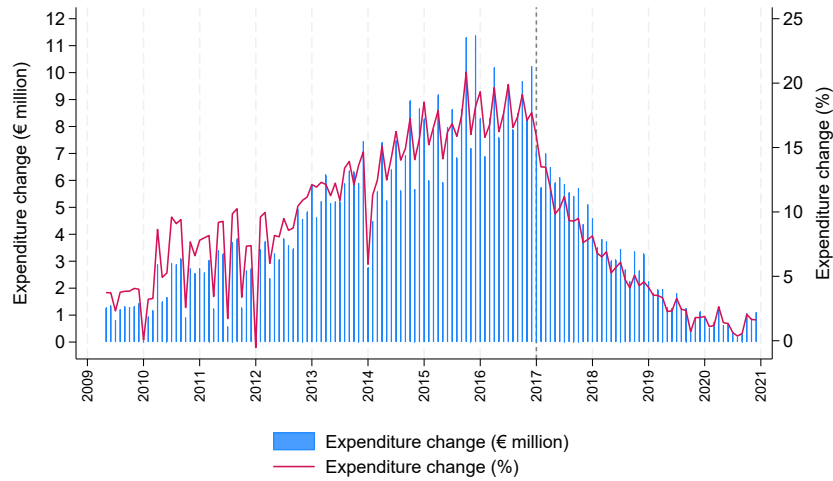
Our first back-of-the-envelope calculation asks what pharmaceutical expenditure would have been if the 2017 reform, which reduced the price band to €0.50, had instead been implemented in 2009. To construct counterfactual auction prices, we again assume that rivals would submit bids equal to their prices at the end of the previous quarter and calculate a product's incentives to deviate under the counterfactual price band. If deviation is not profitable, we use the product's price from the end of the previous quarter. We do the same when deviation is profitable but the corresponding observation is classified as potentially collusive. If deviation is profitable and the observation is not classified as potentially collusive,

we instead assign the product its calculated deviation price.

For non-auction periods, holding other prices fixed, we assume that products whose observed prices lie between the (lower) counterfactual reference price and actual reference price reduce their prices to the counterfactual reference price in order to remain within the price corridor. Using these counterfactual prices, we calculate the resulting change in the total pharmaceutical expenditure.

Figure A-17 shows that introducing the €0.50 price band in 2009 rather than in 2017 would have reduced monthly pharmaceutical expenditure by as much as €10 million, or approximately 20% of total expenditure. A smaller price band limits the extent to which the reference price can increase from one quarter to the next, even when firms continue to follow the focal-pricing rule. It also reduces the size of the price cut required for a deviating firm to undercut its rivals sufficiently to push them outside the new price corridor, thereby making such deviations more attractive.

FIGURE A-17: CHANGE IN THE TOTAL EXPENDITURE - BACK-OF-THE-ENVELOPE CALCULATION 1



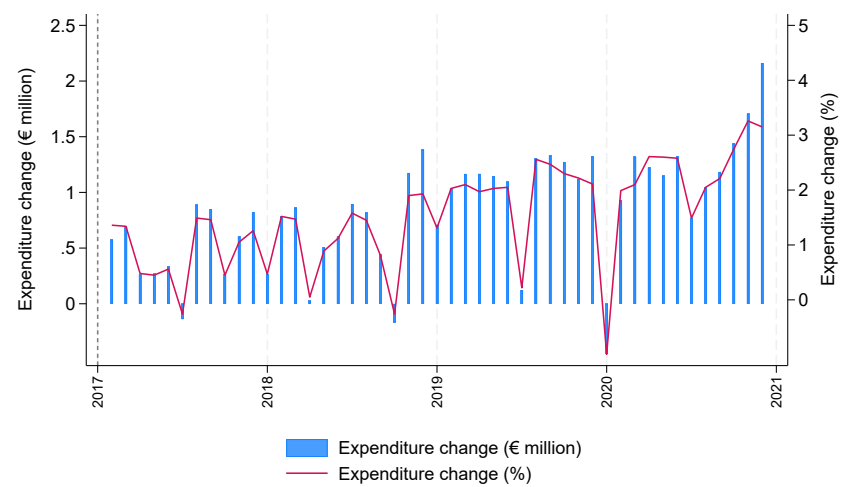
Notes: Data source: Fimea (2009–2020).

The savings accumulate over time, generating a snowball effect as the gap between the simulation and observed price levels widens between 2009 and 2017. Once the €0.50 price band is actually implemented in 2017, the additional savings from the counterfactual reform decline sharply. The remaining savings after 2017 reflect the persistent difference in price levels generated by having introduced the narrower price band earlier.

A-4.2 Back-of-the-envelope calculation 2 - €0.10 price band size

We then consider a second back-of-the-envelope calculation in which the 2017 reform reduces the price band to €0.10 rather than €0.50. Figure A-18 shows that this further reduction in the price band would have generated additional savings of up to €1.5 million per month, corresponding to approximately 3% of total pharmaceutical expenditure.

FIGURE A-18: CHANGE IN THE TOTAL EXPENDITURE - COUNTERFACTUAL 2



Notes: Data source: Fimea (2009–2020).