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market structure:
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Abstract

The present paper evaluates the quantitative impact of a pharmaceutical reform on pharmaceutical prices. A generic substitution policy was introduced in Finland in 2003 to contain rising pharmaceutical expenditure. After the reform pharmacists were obliged to propose a cheaper alternative to a prescribed pharmaceutical product whenever a substitutable product was available. There were three possible channels through which the price effect might have been transmitted. First, the policy might have affected manufacturers' pricing behaviour for existing pharmaceutical products. Second, firms might have introduced new product variants of existing drugs to the market in the form of new generics or different package sizes. Third, the policy might have affected prices through the market structure, with more firms offering new product variants entering the market. Our evaluation is based on non-experimental data for the years 1997–2007 and difference-in-differences estimation techniques that allow for variations in programme effects over time and pre-treatment trends between pharmaceuticals. According to the results, the generic substitution policy has had a greater effect on prices by inducing manufacturers to change their pricing strategy for existing products in the market rather than by increasing the number of product variants or firms in the market. The re-form reduced prices at an increasing rate over time. In 2007 the prices of GS products were 40-45% lower relative to the time before the reform and relative to the respective change in the control group. Within the therapeutic drugs group the prices of close substitutes to generics, at ATC-7 digit level tended to decrease moderately. Controversially, more distant therapeutics, at ATC-4 digit level, prices rose, which may indicate a so-called generic paradox between more distant therapeutic and generic drugs It is reasonable to assume that at the ATC-4 level, where prices tend to increase, there are far less price-sensitive consumers (or physicians) than at the ATC-7 level, where the risk of substitution is more obvious and the proportion of price-sensitive consumers is likely to be greater.

Key words: pharmaceuticals, generic substitution, difference-in-differences, pre-treatment trends, therapeutic competition.

JEL classification numbers: L65, L11, C23

Contents

1. Introduction

Pharmaceuticals have continually captured an increasing share of total health care costs internationally. To curb increasing costs, many countries have reformed their systems for reimbursing medical expenses to patients. These reforms have included various versions of reference pricing and generic substitution.

In Finland, pharmaceuticals accounted for less than 10% of total health care costs in 1990, whereas by the early 2000s the proportion had increased to 16% (Matveinen and Knape 2006, 2011). Since then, the trend has levelled off, mainly due to the generic substitution (GS) policy Finland introduced in April 2003. The reform and publicity around it increased a) consumer awareness of generic alternatives, allowing them to substitute a generic alternative to the prescribed pharmaceutical, and b) competition among manufacturers by making the entry of generic competitors more lucrative. Several reactions followed: incumbent manufacturers changed the pricing of existing drugs; they also introduced both new generics and new package (product) variants of existing drugs to the market, and totally new firms entered the Finnish pharmaceutical market with new generics and package variants. As a consequence, competition increased, generic pharmaceuticals captured increasing market shares and prices fell.

The present paper evaluates, first, the overall quantitative impact of the generic substitution policy on pharmaceutical prices. Second, the paper investigates the relative scales of the reactions: 1) manufacturers' pricing behaviour for existing pharmaceutical products, 2) the introduction of new product variants of existing drugs, and 3) the market structure and the degree to which new firms with new prices entered the market. The policy effect is estimated using panel data and difference-in-differences modelling techniques. According to our results, generic substitution caused significant reductions in the prices of pharmaceuticals. The policy also intensified competition, but the effects on market structure tended to vanish by the end of the evaluation period.

Despite large and increasing pharmaceutical costs there are only a limited number of quantitative evaluations on the effects of different reimbursement schemes on pricing behaviour. The number of studies becomes even smaller when one concentrates on studies with a clearly defined time of intervention, entailing a formal statistical analysis in which the treatment group is observed before and after the intervention and compared with a control group (Brekke et al., 2009; Grootendorst et al. 2005 and 2006; Puig-Junoy 2007; Schneeweiss et al., 2002 and 2003; Marshall et al., 2002; Pavcnik, 2002). Galizzi at al. (2011) provide a comprehensive literature review of the results but also of the methods used to assess the effects of reference pricing policies. There is only one previous paper investigating the effects of the Finnish reform in 2003. Aalto-Setälä (2008)

finds that the average price of substitutable drugs decreased by more than 10% in a relatively short period of time between March 2003 and April 2004.

The closest studies to our own are those of Pavcnik (2002) and Brekke et al. (2009). Studying prices of drugs in several therapeutic categories before and after the introduction of reference pricing, Pavcnik (2002) finds that the reference pricing policy in Germany reduced prices between 10% and 26%. There is a potential problem with the comparison group in this study, however, as it consists of therapeutic substitutes for drugs exposed to reference pricing. There may be cross-price effects that can potentially bias the results.

Brekke et al. (2009) study the relationship between regulatory regimes and pharmaceutical firms' pricing strategies in Norway. A reference pricing system introduced in 2003 for a sub-sample of off-patent pharmaceuticals replaced the price-cap regulation in the reform. The results show that the reform significantly reduced prices of pharmaceuticals in the reference pricing group relative to those in the price-cap group (8% for generics and 19% for brand-name drugs). A novelty in their research is that they are able to quantify the possible cross-price effect on therapeutic substitutes not included in the reference price system. This effect appears to be -2% in their study. The latter finding is an important contribution to the limited literature on therapeutic competition. The finding of Brekke et al. (2009) is in line with the seminal paper by Ellison et al. (1997), who use US data from one therapeutic field (cephalosporin), providing evidence of high-price elasticities between generic substitutes and also significant, though lower, elasticities between therapeutic substitutes.

A main contribution of the present study is to allow for therapeutic competition to occur not only at the 4-digit level but also at the 7-digit level of the ATC classification. The study utilises two distinct groups of therapeutic competitors (henceforth TC groups). The TC1-group includes those pharmaceuticals with GS competitors at the same seven-digit level. These products have the same active substance as the pharmaceuticals in the GS group (treatment group) but have a different strength, form or package size, meaning that they have no GS substitutes. The *TC2*-group includes products with GS competitors at the more aggregated four-digit level, as in Brekke et al. (2009). The third control group is the actual control group (*CG*) which includes pharmacological substances that are non-substitutable and with no substitutable drugs in the same four-digit (or seven-digit) ATC group during the whole study period. These drugs are not related to GS products even in a therapeutic sense.

The paper estimates difference-in-differences panel data models, where the prices of pharmaceuticals in the reform group and various control groups are monitored before and after the reform. Following Wolfers (2006), drug-level variations, as well as programme effects, are allowed to evolve over time. The main finding is that a generic substitution policy has a greater effect on prices by inducing

manufacturers to change their pricing strategy for existing products in the market rather than by increasing competition or the number of firms in the market. The reform reduced prices at an increasing rate over time. In 2007 the prices of GS products were 40-45% lower relative to the time before the reform and relative to the respective change in the control group. The results also show that within the TC group the prices of close substitutes to generics, at the ATC-7 digit level, tended to decrease moderately. Controversially, more distant therapeutics, at the ATC-4 digit level, prices rose, which may indicate a so-called generic paradox between more distant therapeutic and generic drugs. It is reasonable to assume that at the ATC-4 level, where prices tended to increase, there are far fewer price-sensitive consumers (or physicians) than at the ATC-7 level, where the risk of substitution is more obvious and the proportion of price sensitive consumers is likely to be greater.

The rest of the article is organised as follows. Section 2 describes features of the generic substitution reform and the pricing of pharmaceuticals in Finland. Section 3 provides theoretical predictions of how generic substitution might have influenced prices and the market structure (Section 3.1) but also of how therapeutic competitors might have reacted to price reductions for pharmaceuticals in the GS programme (Section 3.2). Sections 4 and 5 describe the data and models used in the empirical analysis. In sections 6 and 7 we present and discuss our empirical findings.

2. The generic substitution reform and the pricing of pharmaceuticals in Finland

A programme of generic substitution (GS) was introduced in Finland in April 2003, with a reference pricing scheme being added in March 2009. Both before and after the 2003 reform manufacturers were free to set the wholesale prices with one notable exception. Drugs reimbursable from the National Social Insurance Scheme were subject to price-cap regulation. The price cap, also referred to in Finnish legislation as a reasonable wholesale price, was and still is determined in negotiations between the pharmaceutical manufacturers and the Finnish Pharmaceutical Pricing Board (FPPB). In the application process the firm proposes a price cap, which is then either accepted or rejected by the FPPB. An accepted price cap defines the maximum price of the pharmaceutical. Although the maximum wholesale prices are regulated, the price-cap regulation allows for a reduction in prices. Also, there is no price cap for pharmaceuticals outside the reimbursement scheme. Price regulation is prevalent in the Finnish pharmaceutical market because 77% of pharmaceuticals consumed in outpatient care are subject to reimbursement from the National Social Insurance Scheme (Timonen et al., 2005).

Since the government sets the fixed retail mark-ups for reimbursed drugs, price competition prevails only at the manufacturer level. Manufacturers have to sell the drugs at the same wholesale prices to all pharmacies and pharmacies are only allowed to add a fixed mark-up to the wholesale prices (Timonen et al., 2005). Therefore, the empirical analysis in the present paper will focus on wholesale prices.

There were generic alternatives in the market even before the reform. The generic substitution scheme obliged pharmacists to propose a substitution for a drug to patients whenever physicians prescribe a drug that is not the cheapest substitutable medicinal product, i.e. in the price corridor. A substitution drug is offered from at prices lower than the upper limit of the price corridor. A pharmacy is also allowed to sell a drug close to the cheapest if it has run out of the cheapest drug.[1] The Finnish Medicines Agency (FIMEA, earlier the National Agency for Medicines) maintains the list of substitutable medicinal products that are biologically equivalent and contain the same active substance in equal amounts and pharmaceutical form (Hartikainen-Herranen and Paldan, 2005). Not all products with the same active substance come under the generic substitution scheme. To gain substitution status the product must have the active substance in a certain amount and form.

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[1] The price of a prescribed medicine is considered to be close to the cheapest when the price difference to the cheapest generic alternative is less than €2 (for products costing less than €40) or when the price difference to the cheapest is less than €3 (for those costing at least €40).

Both the prescribing physician and the purchasing individual could decline the substitution. If the physician wanted to prevent the replacement, it had to be done in advance, as pharmacists did not tell the physician if they made a replacement. The customer could decline substitution at the counter. If the patient declined the substitution, the potential saving arising from the consumption of a cheaper pharmaceutical was lost. In this respect denial of substitution was not totally costless for the patient.

Drug advertising is tightly regulated in Finland. Furthermore, direct-to-consumer advertising (DTCA) does not exist due to legal issues relating to drugs dispensed by prescription only (Finnish Drugs Act 1987/395). However, drug firms are allowed to advertise their products directly to healthcare professionals via *detailing* for example.

3.   Theoretical predictions on the impact of generic substitution

3.1 Information and the market response after the GS reform

Generic substitution as implemented in Finland provided incentives for patients to substitute expensive pharmaceutical treatments for inexpensive bioequivalent treatments. Theoretically speaking, this can happen through increased information about the low-priced alternatives. Before generic substitution a patient might not have been aware of low-priced generic pharmaceuticals. After the generic substitution reform, the pharmacist informs the patient about cheaper generic alternatives and suggests substituting an expensive prescribed pharmaceutical for an inexpensive generic product. Because the patient could still decline the substitution, generic substitution essentially increases price and product information in the market. Economic theory predicts that increased price information increases demand elasticities and intensifies price competition (Grossman and Shapiro, 1984). Secondly, implementation of generic substitution in Finland may have led to price reductions, because the price corridor provided firms an incentive to be among the cheapest. We therefore expect generic substitution to intensify price competition and reduce prices.

Generic substitution may also intensify price competition through its effect on the market structure. If generic substitution induces new firms to enter the market, price competition may be fiercer after the reform simply because the market structure is more competitive. The profitability of generic entry may have been enhanced since the implementation of generic substitution, because the price corridor directly supports demand for inexpensive pharmaceuticals, which are typically generic products. Increased profitability may be a short-run phenomenon only, because in the long run the entry of generic products will reduce prices and the profitability of both potential entrants and incumbents in the market. For this reason we expect that in the short run the generic substitution will increase the number of competitors, but that this effect will level off in the long run after abnormal profits have been eliminated. And because of this predicted development in the market structure, price reductions due to a more competitive market structure are also expected to vanish in the long run. Despite this, generic substitution may still cause price reductions among incumbent products because patients are more informed. The following table summarises the expected effects of generic substitution on prices and market structure.

Table 1.   *Expected effects of generic substitution on prices and the number of competitors*

	Short run	Long run
Prices, p	$\Delta p < 0$	$\Delta p \leq 0$
Number of competitors, n	$\Delta n > 0$	$\Delta n = 0$

3.2 Loyal consumers and optimal price response to generic competition

The current literature analysing generic competition in pharmaceutical markets suggests that generic entry may lead to two kinds of market outcomes. The first prediction is in line with standard economic theory and suggests that the entry of generic pharmaceuticals intensifies price competition in the market and reduces prices of all substitute (both branded and generic) products. The central mechanism behind this result is that the entry of low-priced generic pharmaceuticals creates price competition among incumbent generic products but also causes the branded firm to reduce its price in competition for market shares. The empirical findings of Aronsson et al. (2001), Brekke et al. (2009) and Wiggins and Maness (2004) are consistent with this first prediction.

The other market outcome is called the generic paradox due to the unorthodox response of the prices of branded pharmaceuticals to intensified generic competition. The generic paradox occurs when the entry of generic pharmaceuticals increases the price of a branded pharmaceutical. Frank and Salkever (1992) were the first to study the generic paradox with theoretical methods. They examined Stackelberg price competition between a branded pharmaceutical (a leader) and generic products (followers). The authors examined a market where the demand for the branded pharmaceutical consists of price-sensitive and loyal consumers. The consumption decisions of price-sensitive consumers depend on the prices of the branded and generic pharmaceuticals, but loyal consumers consume only the branded pharmaceutical. One of the main results of Frank and Salkever (1992) is that the entry of generic pharmaceuticals may decrease the price elasticity of the reduced-form demand of the branded pharmaceutical, leaving room for the branded firm to raise its price. Frank and Salkever (1997), Grabowski and Vernon (1992) and Regan (2008) provide empirical evidence supporting this prediction.

The model of Frank and Salkever (1992) examines price competition between branded and generic pharmaceuticals with the same chemical substance, possibly with advertising competition, but their results may not apply to a market environment with quality differences between competing pharmaceuticals. The quality differences may be spurious, which several authors (see e.g. Jelovac and

Bordoy, 2007, Kong, 2009) have cited as an explanation for the observed price differences between branded and generic pharmaceuticals. The quality differences may also be real, which occurs when a pharmaceutical product competes with pharmaceuticals containing a different chemical substance. The latter market environment has been called therapeutic competition (see e.g. Brekke et al., 2007). The model that we develop below can be interpreted from either of the above perspectives. Our model builds on Frank and Salkever (1992) and quality models by Shaked and Sutton (1982) and Motta (1993). The model's predictions are used to interpret the price reactions of therapeutic competitors to the price competition from generic products that we observe in our data.

Let us consider a market with two firms, firms 1 and 2, producing pharmaceuticals 1 and 2. The two pharmaceuticals are differentiated in terms of quality. In practice, quality may be an indicator of the health benefits of a pharmaceutical. Let us denote the quality of the firm i's product as q_i, where i = 1, 2. We assume that firm 2 sells a high-quality product, and $0 < q_1 \leq q_2$. When the quality difference between the two pharmaceuticals is sufficiently high, it may be that consumers (physicians and patients) do not consider the pharmaceuticals as substitute products. To rule out this possibility, we require throughout the following analysis that $q_2 < 2q_1$ or alternatively that $\Delta/q_1 < 1$, where $\Delta \equiv q_2 - q_1$. This condition implies that the quality of pharmaceutical 2 cannot be more than 100% better than that of pharmaceutical 1. The prices of the drugs are denoted as p_1 and p_2. Both pharmaceuticals are produced at a constant marginal cost c, which is assumed to be zero (see e.g. Jelovac and Bordoy, 2006, Brekke et al., 2007).

The market consists of two different types of consumers: loyal and price-sensitive consumers (Frank and Salkever, 1992). The fraction α of the consumer population is loyal and the rest are price-sensitive. Willingness to pay for quality is denoted as θ and is assumed to be uniform $U[0,1]$-distributed in the consumer population. Each consumer consumes at most one unit of either pharmaceutical or no pharmaceuticals at all. The consumer with willingness to pay θ obtains utility

$$U(i) = \theta q_i - p_i \qquad (1.1)$$

if she consumes pharmaceutical i = 1,2, and zero utility of she goes for an outside option with no pharmaceutical consumption. The demands in the price-sensitive segment of the market are defined as follows (see Motta, 1993):

$$d_1 = \frac{1}{\Delta}\left(p_2 - \frac{q_2}{q_1}p_1\right) \qquad (1.2)$$

and

$$d_2{}^s = 1 - \left(\frac{p_2 - p_1}{\Delta} \right).$$

(1.3)

Loyal consumers are loyal to pharmaceutical 2 despite any price differences between the two drugs. This implies that firm 2 is a monopoly producer in a market segment consisting of loyal consumers. Hence the demand for pharmaceutical 2 in that market segment is defined as follows:

$$d_2{}^l = \frac{1}{q_2}(q_2 - p_2).$$

(1.4)

Our interest is focused on the best response of firm 2 and, therefore, we next concentrate on the demand and profit of pharmaceutical 2. The demand for pharmaceutical 2 is defined as follows:

$$D_2(p) = \begin{cases} \left(1 - \dfrac{p_2}{q_2}\right), & \text{if } 0 \le p_2 \le \dfrac{q_2}{q_1} p_1 \\[2ex] \alpha\left(1 - \dfrac{p_2}{q_2}\right) + (1-\alpha)\left(1 - \dfrac{1}{\Delta}(p_2 - p_1)\right), & \text{if } \dfrac{q_2}{q_1} p_1 < p_2 < p_1 + \Delta \\[2ex] \alpha\left(1 - \dfrac{p_2}{q_2}\right), & \text{if } p_1 + \Delta \le p_2 \le q_2, \end{cases}$$

(1.5)

where $p = (p_1, p_2)$ are the prices of the two pharmaceuticals. The profit function of firm 2 is defined as $\pi_2 = p_2 D_2(p)$.

The above demand function deserves some comments. When the price of pharmaceutical 2 is sufficiently high, price-sensitive consumers prefer to buy the low-quality pharmaceutical, in which case only loyal consumers purchase pharmaceutical 2. That segment of the market is called the loyal segment. When firm 2 reduces its prices below the threshold value $p_1 + \Delta$, some price-sensitive consumers are willing to purchase pharmaceutical 2. That segment of the market is referred to as the price-sensitive segment. When the price of pharmaceutical 2 is low, below the threshold value $(q_2/q_1)p_1$, both price-sensitive and loyal consumers purchase the monopoly quantity (1.4), which constitutes the demand function of pharmaceutical 2. We call the last segment the monopoly segment.

The main theoretical result is presented in the following proposition. Our interest is focused on examining the behaviour of the best-response function of firm 2, $p_2(p_1)$, which contains the basic information about how firm 2 reacts to price changes by firm 1. We show that the best-response function increases

monotonically (the two pharmaceuticals are strategic complements) where there are only few loyal consumers in the market (see Figure 1, Case 2). In that case the best response of firm 2 to a price reduction in the rival product is to choose a less expensive price (see also Brekke et al., 2009). On the other hand, if the market consists mainly of loyal consumers, a reduction in the price of product 1 may also cause product 2 to increase its price[2] (see Figure 1, Case 1).

Proposition If $\alpha \geq \Delta/q_1$, then the best-response function of firm 2 is

$$
p_2(p_1) = \begin{cases}
\dfrac{q_2}{2}, & \text{if } 0 \leq p_1 \leq \hat{p}_1 \\[2ex]
\dfrac{q_2\left[(1-\alpha)p_1+\Delta\right]}{2\left[\alpha\Delta+(1-\alpha)q_2\right]}, & \text{if } \hat{p}_1 < p_1 \leq p_1^2 \\[2ex]
\left(\dfrac{q_2}{q_1}\right)p_1, & \text{if } p_1^2 < p_1 \leq \dfrac{q_1}{2} \\[2ex]
\dfrac{q_2}{2}, & \text{if } p_1 > \dfrac{q_1}{2}.
\end{cases}
$$

Otherwise, if $\alpha < \Delta/q_1$, the best-response of firm 2 is

$$
p_2(p_1) = \begin{cases}
\dfrac{q_2\left[(1-\alpha)p_1+\Delta\right]}{2\left[\alpha\Delta+(1-\alpha)q_2\right]}, & \text{if } 0 \leq p_1 \leq p_1^2 \\[2ex]
\left(\dfrac{q_2}{q_1}\right)p_1, & \text{if } p_1^2 < p_1 \leq \dfrac{q_1}{2} \\[2ex]
\dfrac{q_2}{2}, & \text{if } p_1 > \dfrac{q_1}{2},
\end{cases}
$$

where

$$
\hat{p}_1 \equiv \frac{-\Delta + \sqrt{\alpha\Delta(\alpha\Delta+(1-\alpha)q_2)}}{1-\alpha}
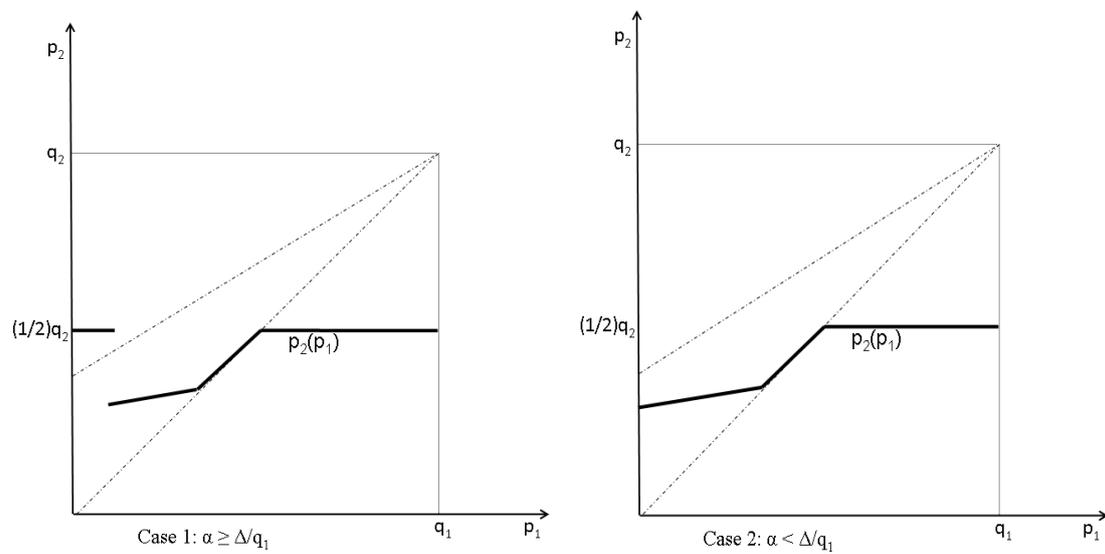$$

and

$$
p_1^2 \equiv \frac{q_1\Delta}{\Delta+\alpha\Delta+(1-\alpha)q_2}.
$$

Proof. See Appendix 1

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[2] This occurs in particular when price p_1 becomes sufficiently low.

Figure 1.   Price response of firm 2

4. Data

4.1 Classifications

We obtained data from the Finnish Medicines Agency. Our data contain drugs from eight 3-digit ATC groups: A02, C07, C08, C09, C10, N03, N05, and N06. Altogether there are 158 different active substances (henceforth also drugs) at the 7-digit ATC level (see Appendix 2).

The unit of observation is even more disaggregated, however, when referring to a product. For the same drug there can be several products defined by the manufacturer, the number of daily dosages per package (DDD), the size of the package (in millilitres or grams), and the strength of one tablet or unit in a package (in millilitres or grams). Some of the products refer to the original brand name drug and others to the generic substitutes or parallel imported products. The data at hand do not distinguish between brand name and generic products.

The data are spread over 44 three-month periods, starting from the first quarter of 1997 and ending at the fourth quarter of 2007. The data set is an unbalanced panel data set due to the entry and exit of pharmaceutical products. In the whole data set there are some 48,000 observations referring to a product over a three-month period.[3]

The paper examines prices mainly in three distinct groups of pharmaceuticals. The first group includes products that were i) either subject to generic substitution from the 2nd quarter of 2003 onwards or ii) entered the programme later during the period of investigation. This group of products is called the generic substitution group (the GS group).

The second group includes products that are non-substitutable over the whole observation period, but belong to a 4-digit level ATC group containing some substitutable products (altogether there are 15 4-digit ATC groups in the data). These products are called therapeutic competitors (the TC group), because the active substances in these groups are developed to treat the same medical condition as those in the GS group, but for some reason these pharmaceuticals are not part of the substitution programme.

In order to go deeper in checking the validity of the control group and to learn more about reactions in the therapeutic competitors group, we also use another categorisation where the therapeutic competitors group is split into two. The first (TC1) includes those products with GS competitor(s) at the same disaggregated

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[3] The raw data include more than 53,000 observations. We use a cleaned data set where odd changes in prices, less than one year appearances, and missing observations in the middle of a series were removed from the data.

seven-digit level, i.e. the same drug. These TC1 products contain the same active substance as the products in the GS group but have a strength, form or package size that makes them non-substitutable in the generic substitution programme. The second group (TC2) includes products that have GS competitor(s) only at a more aggregated four-digit level. The separation of the TC group into the TC1 and TC2 groups reveals the level at which therapeutic substitution is most prevalent. Brekke et al. (2009) argue that therapeutic substitution may occur at the 4-digit level, whereas we allow this to happen both at the 4- and 7-digit levels.

Since the inclusion of therapeutic substitutes in the control group may bias the results, we also use another control group, which includes products that are non-substitutable in the GS programme and face no competition from any substitutable drug in the same 4-digit ATC group. This category is called the control group (the CG group), since these drugs are not substitutable nor are they related to any product in the GS group in a therapeutic sense.

The period of investigation spans from the first quarter of 1997 to the fourth quarter of 2007. The total number of different drugs (different ATC codes at the 7-digit level) remains stable, particularly after the third quarter. Then, the total number is between 118 and 134. However, the number of GS drugs increases more or less over the whole period (Figure 2). A large majority of drugs that become substitutable do so at the beginning of the programme in quarter 26 ("GS after participation"), which refers to the second quarter of 2003. Less than 20 drugs become substitutable after quarter 26 ("GS before participation"). Very few drugs participate in the programme only for the last two periods. The last drugs entering the programme do so after quarter 42 (the curve reaches zero in the last 2 quarters, where quarter 44 refers to the fourth quarter of 2007). The number of different drugs in the therapeutic competitor groups (including both TC1 and TC2) first increases and then after the policy reform starts declining. The number of drugs sold in the market in the control group, CG, remains stable until period 19, after which it also starts declining.

Figure 2.   Number of different drugs in the three groups
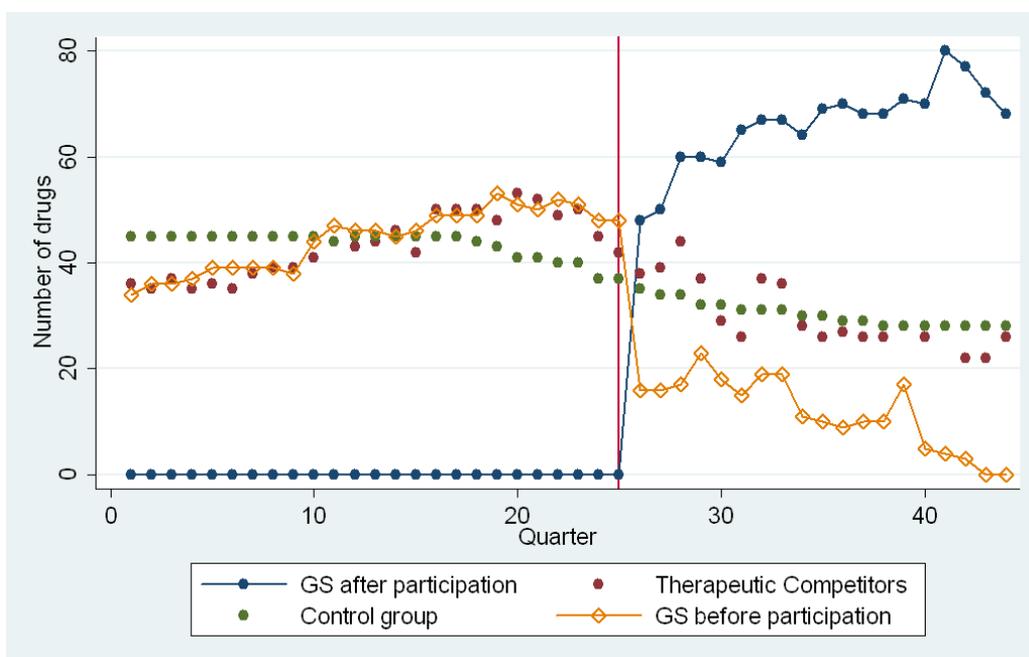
4.2 Changes in prices

The variable of interest, the price of a product, is measured relative to the daily dosage (price per DDD, €) and refers to the average wholesale price of the product over a three month period. A similar definition of the unit price has been used widely in the literature on pharmaceutical markets (see e.g. Brekke et al., 2009; Pavcnik, 2002; Ellison et al., 1997). We present basic statistics on the prices of pharmaceutical products in the GS, CG and TC groups in Table 2.

Table 2.   Summary statistics on the price variable in different groups

	Obs.	Mean	Std. Dev.	Min	Max
GS	27019	0.666	0.940	0.019	12.730
CG	2738	0.467	0.174	0.125	0.812
TC	18454	1.324	3.613	0.026	71.805

In order to have a better understanding of the price trend over time, we next present the trend of average prices in the GS, CG and TC groups. The last group consists of all pharmaceuticals in the 4-digit ATC group containing at least one product in the generic substitution programme, i.e. products in the TC group. The mean price of products in the GS group is very stable in the pre-treatment period, whereas the price trend turns downwards right after the reform and turns slightly back up towards the end of the investigation period (Figure 3). The TC group

shows an increasing trend before the reform and the trend becomes even slightly steeper after the reform. This may happen if the cross-price elasticity of the products in the TC and GS groups is small, and a firm selling a TC product does not lose demand when raising the price of its product. This certainly takes place when the share of loyal consumers in the market is large, as suggested by the theoretical model in Section 3.2. Therefore we explain the increasing trend in the prices of TC products by the presence of a large number of loyal consumers (physicians and patients) in the market. In practice, loyalty may arise from the fact that pharmaceuticals in the TC and CG groups differ so much that consumers do not consider any two products as close substitutes.

Figure 3.   *The mean price per daily dosage in three groups of drugs*
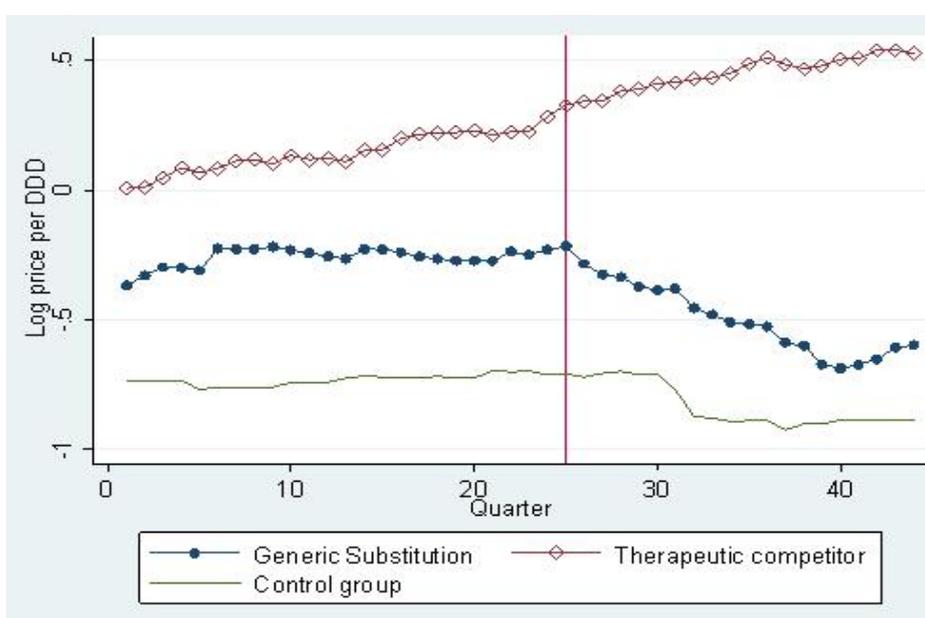
Simple averages within groups may hide varying developments in volumes sold. Weighting the drugs according to volumes sold shows the trend of the effective prices in the market from the consumers' point of view. When we look at the log of total euros per DDD sold, the decrease in prices of GS products appears to be stronger than above (Figure 4). A stronger decline suggests that cheaper drugs are gaining more market share. The trends in the TC and CG groups observed above also remain in the weighted figure.

*Figure 4.   Log of weighted drug prices in the three groups*
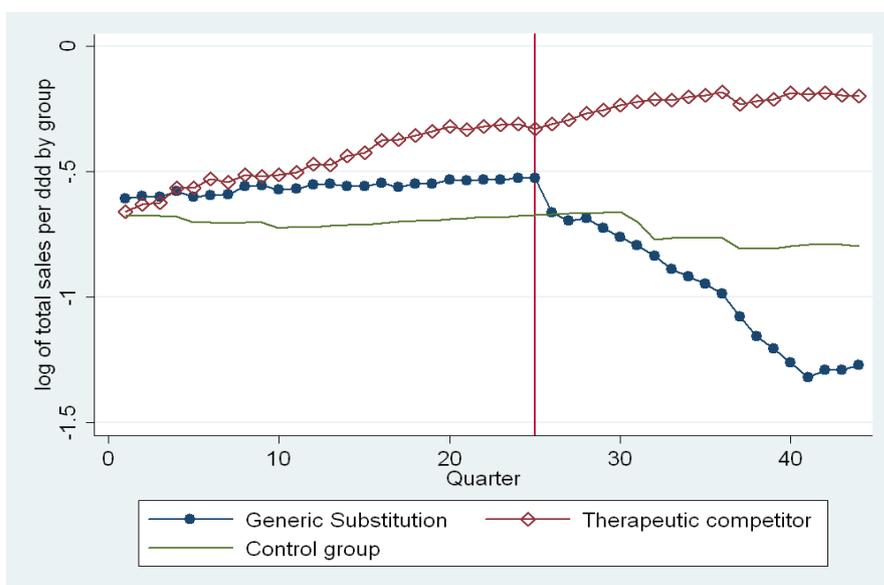
Visually discernible differences in price trends between the groups before the reform must be taken into account in the estimation (Wolfers 2006).[4] If the differences in trends were not controlled for, they would interfere with the estimate of the reform effect. For example, an increasing trend of the TC group relative to the GS group would make the estimated price decrease larger than what it actually was. Pre-treatment trends are statistically investigated in Appendix 3.

4.3 New product variants and firms

The prices of GS drugs decrease if manufacturers change their pricing policies for existing products or incumbent and entrant manufacturers introduce new cheaper generics and product variants (package versions) to the market. The number of different product versions in the GS group increases particularly right after the reform, then declines towards the end of the investigation period (Figure 5). The changes coincide with the price trend of the GS drugs. In contrast, the number of different product versions of CG drugs declines radically over time. Product variants are less common in the TC group, a finding that applies particularly to TC1 products rather than TC2 products (feature not shown in Figure 5).

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[4] Since there are more than 1200 different products in the data at hand and on average only 33 time series observations per product, we are not concerned about possible unit root processes (Woolridge 2002).

Figure 5.   Number of different product versions per drug.
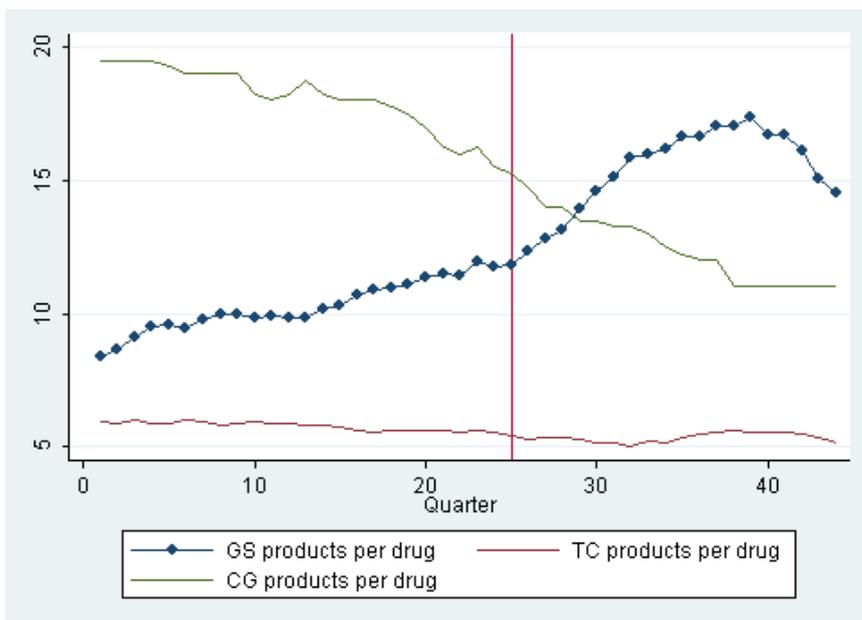
New generics or product variants can be introduced to the market by incumbents and entrants. The number of distinct firms[5] selling the same GS drugs increases strongly right after the reform and decreases somewhat towards the end of the investigation period (Figure 5). The number of distinct firms selling the same TC or CG drugs remains fairly stable. The number of different firms decreases towards the end of the investigation period, which coincides with the change in the price trend of the GS drugs.

Figure 6.   Number of distinct firms per drug by group

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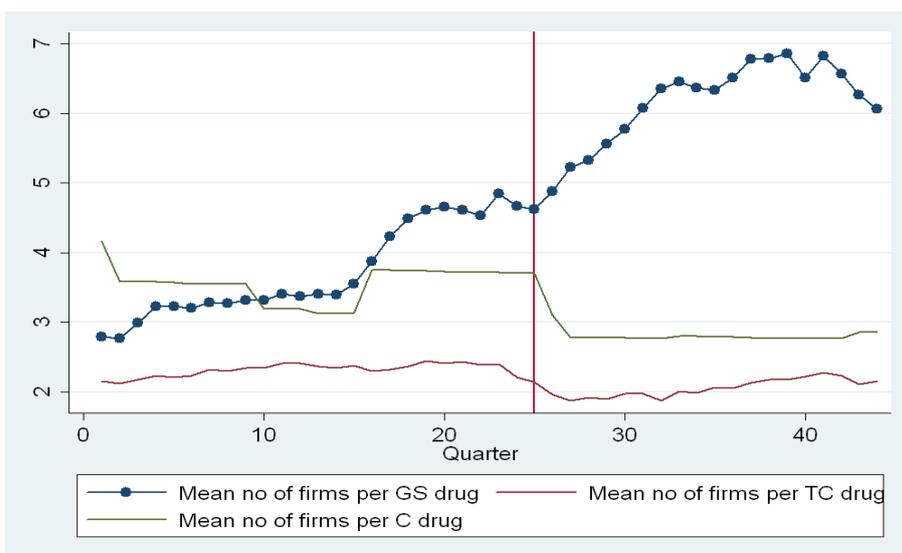
[5] Firms with subsidiary or affiliated companies are classified as one company.

The increasing number of firms in the market shows up well in the level of competition measured by the Herfindahl index, which sums the squared market shares of firms by drug (Figure 7). The measure is higher the more concentrated the market is. Therefore, stronger competition decreases the index. Towards the end of the period the severity of competition decreases in the treatment group. Competitive pressure decreases slightly in the two control groups over time.

Figure 7.   Herfinhal index by quarter
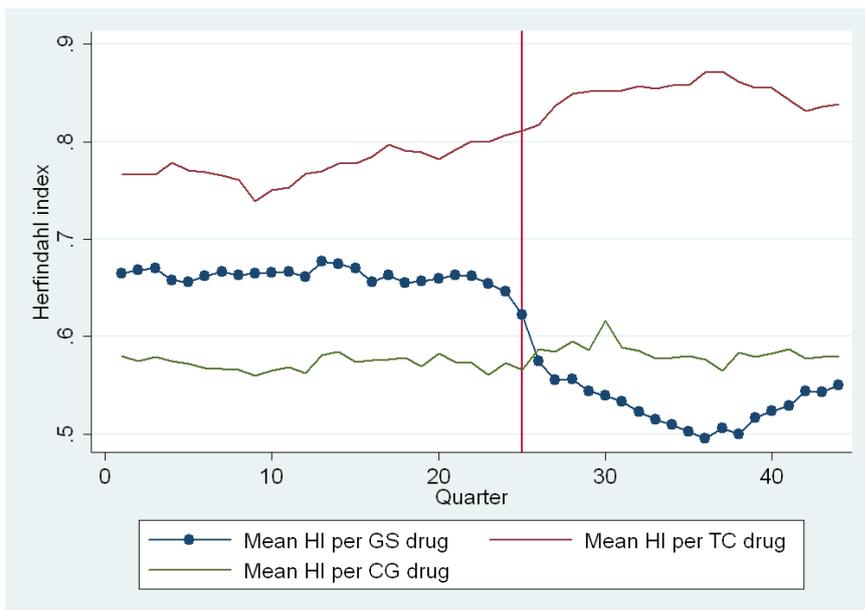
5. Empirical models

The empirical analysis proceeds in three steps. The first part estimates the overall effect of the reform on prices with and without trends and weights, and checks the robustness of various control groups, i.e. CG, TC1 and TC2. Then, the second part analyses the extent to which the estimated price effect is due to incumbent products getting less expensive relative to the alternative, where the expansion of the GS programme and the introduction of new products account for the results found. The third part scrutinises the extent to which new firms affect prices, and the final part examines to what extent the reform has affected the market structure and level of competition.

The price model

The basic estimated model for the price analysis is:

$$\ln(price)_{i,t} = \phi + \sum_{j=1}^{6} \alpha_j Participation_{i,t,j} + \beta_1 GS_i + \beta_2 TC1_i + \beta_3 TC2_i$$

$$+ \sum_{c=1}^{4} \gamma_c control_{i,t,c} + \sum_{d=2}^{158} \delta_d drug_d + \sum_{t=2}^{44} \tau_t time_t + \sum_{d=2}^{158} \chi_d drug_d * trend_t + \varepsilon_{i,t} \qquad (1.6)$$

where *ln(price)$_{i,t}$* refers to the logarithmic price per daily dosage of product i in time period t. Six 'participation' variables (j=1,…,6) indicate the length of time observation i has participated in the programme. Each of the six dummies refers to time intervals of three (or four) quarters. For the majority of the GS drugs the participation dummy number 1 (j=1) is one in the 26th, 27th and 28th quarter (zero otherwise), the second participation dummy is one from the 29th to the 31st quarter, and so on. The last period dummy includes four quarters (41th – 44th quarter), and all products with 1 in the Participation 6 dummy variable have been in the programme from the beginning in April 2003 (time period 26). For those drugs that enter the programme later than in period 26, the participation dummies refer to later time periods accordingly, and for those products there are less than six participation dummies with value 1. As can be seen in Figure 1 above, the latest arrivals are only included in the Participation 1 dummy, since they participate in the programme in the two last periods (43 and 44).

Rather than using one participation variable only, splitting it up into six distinct dummies makes it possible to detect any changes in the programme effect over time. It also remedies the risk of confounding pre-existing trends with the policy impact (Wolfers, 2006). Since the characteristics of different products are controlled for (with product DDD, product strength, package size, and age of the product) and the drug-level fixed effects (drug$_d$ variables) and time dummies (time$_t$ variables) are included, the coefficients α_1-α_6 capture the average programme effect over time for the GS drugs relative to the control group. The

baseline model is first estimated by OLS and then by weighted least squares, where sales of one product relative to the total sales in a period are used as weights. Finally, the 'drug times trend' interaction variables control for the pre-treatment trends. The other variables are described above.

The model for market structure

For modelling the policy effects on the market structure, the data are aggregated up to the drug level. The structure of the model is rather similar to the previous one, apart from a different dependent variable. Now we model the effect of the reform on the log of the Herfindahl index.

$$\ln(Herfindahl)_{d,t} = \phi + \sum_{j=1}^{6} \alpha_j Participation_{j,d,t} + \sum_{c=1}^{4} \gamma_c \overline{control}_{d,t}$$

$$+ \sum_{d=2}^{158} \delta_d drug_d + \sum_{t=2}^{44} \tau_t time_t + \varepsilon_{d,t} \tag{1.7}$$

The participation dummy turns on when at least one product with the same active substance participates in the GS programme. The control variables are now the means of different products with the same active ingredient. Distinct GS or TC dummies are no longer needed, since the fixed effects included in the model are at the same level of aggregation as the group dummies.

6.   Results

6.1 Baseline and robustness checks

A first specification of the price model (equation (1.6) above) excludes weights and the drug-level trends and suggests that prices of GS drugs drop by 20 per cent during the first three quarters when the GS drugs are in the programme (Figure 8). The effect increases over time, reaching -45 per cent by the fourth participation period (10th–12th quarter after start of the reform) and levelling off after that. Very narrow confidence intervals (CI- and CI+) indicate precisely estimated coefficients. When the drug-level trends are added and the equation is estimated by weighting the volumes sold, the effect is first smaller, but eventually reaches the same level as in the first specification. This indicates that drugs that get cheaper over time also gain more dominance in the market. The latter specification is called the baseline and all the specifications below it will be compared to this baseline model.

Figure 8.   Total price effect over time
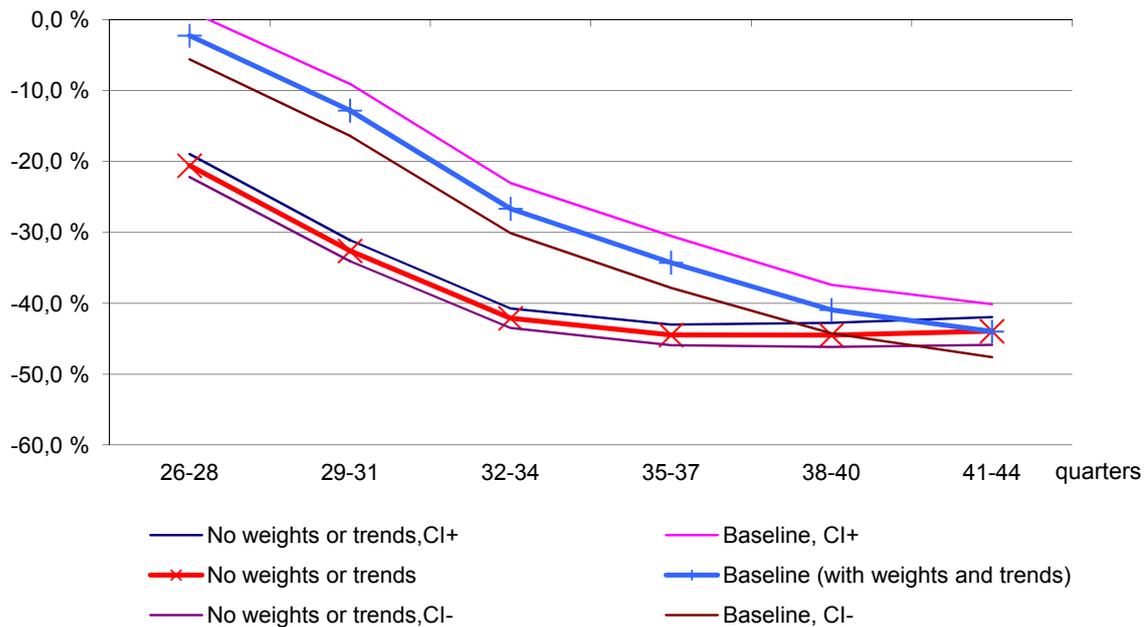
We present the results of the model without weights and drug level trends, henceforth Model 1, and the baseline model in Table 3 below. In the baseline model the estimated parameters of the participation dummies from 2 to 6 indicate significant differences between the prices of GS group and CG group products, while in Model 1 the price effects tend to be slightly greater, causing all the parameter estimates of the participation dummies to be statistically significant. In order to estimate the price differences in percentage terms, as displayed in Figure 8, we used transformations $\exp(\alpha_j) - 1$ for $j =1,2,...,6$. The high value of R^2

shows that the variables included in the baseline model (also Model 1) explain the variation in the prices of pharmaceuticals well.

Adding weights turns the effect curve clockwise, so that the effect is initially smaller and eventually larger in the weighted specifications (Figure 8 and Table 3). This finding applies to the specifications both with and without trends (not reported in figure). Adding drug-level trends, in turn, decreases the estimated effect during each participation dummy, implying that part of the estimated effect without trends includes differences in price trends that are not related to the reform (not reported in figure).

Table 3.   *Results of Model 1 and baseline model*

Dependent variable: ln(price per DDD)

Explanatory variable	Model 1 (no weights, no trends)				Baseline model (with weights and trends)			
	Coefficient	Std. Err.	[95% Conf. Interval]		Coefficient	Std. Err.	[95% Conf. Interval]	
Participation 1	-0.2301***	0.010	-0.251	-0.210	-0.0223	0.018	-0.057	0.013
Participation 2	-0.3943***	0.011	-0.416	-0.372	-0.1367***	0.021	-0.179	-0.095
Participation 3	-0.5465***	0.012	-0.570	-0.523	-0.3097***	0.025	-0.358	-0.261
Participation 4	-0.5882***	0.013	-0.614	-0.562	-0.4194***	0.028	-0.475	-0.364
Participation 5	-0.5885***	0.016	-0.619	-0.558	-0.5262***	0.030	-0.584	-0.468
Participation 6	-0.5784***	0.018	-0.613	-0.543	-0.5793***	0.034	-0.646	-0.513
GS dummy	-0.4147***	0.017	-0.448	-0.381	-0.4085***	0.034	-0.474	-0.343
TC1 dummy	-0.4021***	0.016	-0.433	-0.371	-0.5214***	0.034	-0.588	-0.455
TC2 dummy	-0.4455***	0.010	-0.464	-0.427	-0.5029***	0.025	-0.552	-0.454
ln (DDD per product)	-0.2658***	0.004	-0.273	-0.259	-0.1911***	0.004	-0.199	-0.183
ln (strength of one pill of the product)	-0.0392***	0.003	-0.045	-0.033	-0.0379***	0.005	-0.048	-0.027
ln (number of pills in the product)	0.0145***	0.002	0.010	0.019	0.0231***	0.003	0.016	0.030
Length of stay in the market (quarters)	0.0200***	0.000	0.019	0.021	0.0200***	0.001	0.019	0.021
Constant	0.4360***	0.026	0.386	0.486	0.2637***	0.033	0.200	0.328
Drug level trends	No				Yes, F=79.88***			
Drug fixed effects	Yes, F=3000.07***				Yes, F=1328.91***			
Time dummies	Yes, F=127.21***				Yes, F=12.22***			
F-test (model sign.)	3813.52***				5396.37***			
R^2	0.828				0.921			
N	47466				47466			

*** $p < 0.01$

Assuming that drug companies anticipated the policy change, they could have started re-pricing products before the actual policy reform. To model this option, we added two dummies to the baseline specification to indicate whether the product in question will enter the GS programme in 1-3 quarters or in 4-6 quarters. It appears that GS prices tended to increase close to the policy reform. After controlling for this phenomenon, the estimated policy effect after the reform remains very similar relative to the baseline specification. In the baseline the effect is -41 per cent during the Participation 5 dummy (quarters 38-40) and -45 per cent during the Participation 6 dummy (quarters 41-44). In the specification allowing for anticipation of the reform, the respective estimates are -42 per cent and -42 per cent (not reported in figure but obtained from the authors).

Returning to the baseline specification, the exclusion of CG drugs from the sample does not change the results (Figure 9). In contrast, the baseline result drops somewhat when groups TC1 and TC2 are jointly excluded (not reported in the figure), implying that firms selling products in the TC group increased prices in response to decreasing prices in the GS group (see Figure 9). Splitting the TC group into two parts shows that the exclusion of the more distant therapeutic competitors (TC2) decreases the estimated effect, whereas the exclusion of the more close TC1s increases it (Figure 9). This indicates that manufacturers increased the prices of TC2 products as a reaction to the reform, because a comparison of GS with TC1 and CG (excluding TC2) gives a smaller programme effect than that of GS to all three comparison groups.

*Figure 9.*   *The price effect of the GS group relative to the various control groups*
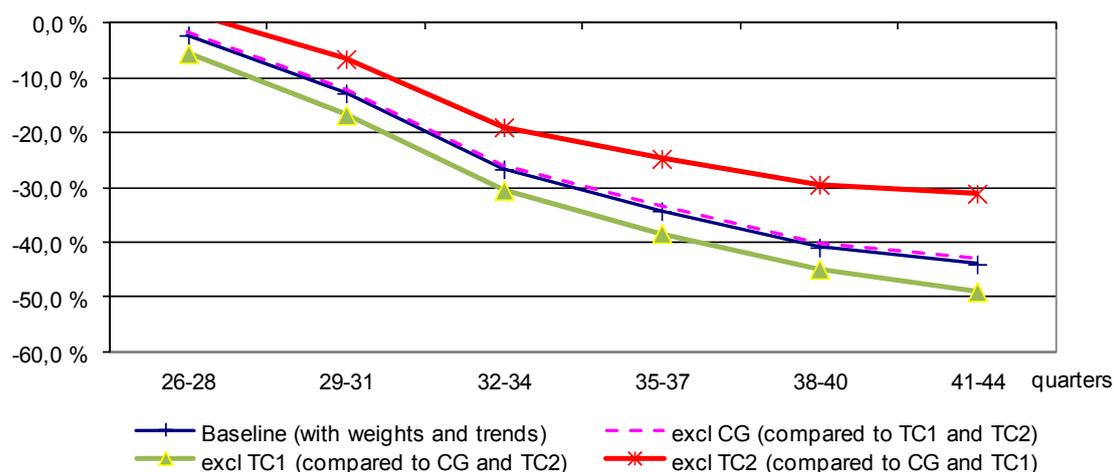
This issue can also be analysed differently by introducing 12 new dummies to the model, i.e. six new dummies both for TC1 and TC2 products. These dummies

refer to the three (or four) quarter periods after the reform, similarly to the Participation 1 – Participation 6 dummies for the GS products that were in the programme from its beginning in period 26. Thus this specification has a total of 18 dummies modelling the effect of the reform on GS, TC1 and TC2 products relative to the control group (CG). As with the specification above, the results here indicate that the prices of TC2 drugs became more expensive in reaction to the reform even though the specification includes drug-specific trends (Figure 10). The effect on GS drugs is somewhat smaller, corresponding to a 5 per cent reduction at the end of the period (- 40% instead of - 45%).

*Figure 10.   Effects of reform on GS, TC1 and TC2 drugs relative to the control group*
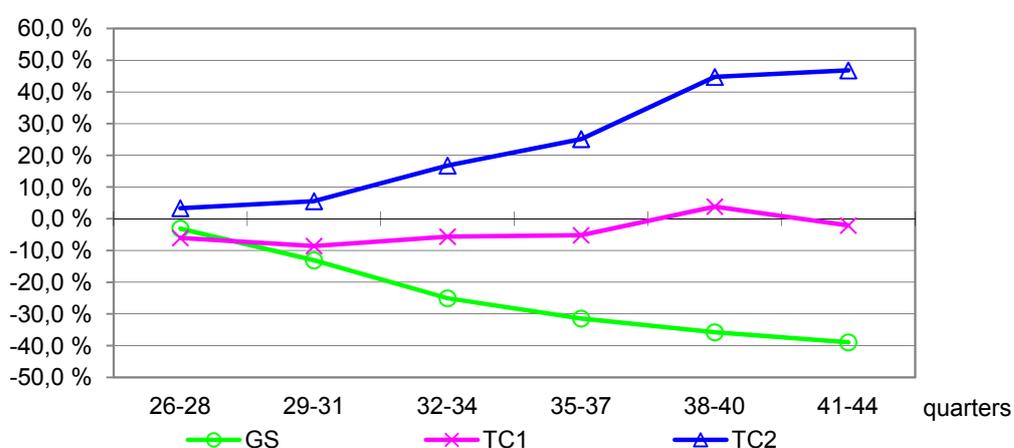
6.2 Role of programme expansion, new product versions and new firms

The baseline result remains when all those drugs (ATC 7-digit level) that entered the market after the policy reform are excluded from the sample (keeping the control groups as they are in the baseline) (Figure 11). This result is as expected, since only a few totally new pharmaceuticals were introduced to the market during the period of investigation.

In contrast, the exclusion of new product versions from the sample strongly magnifies the negative effect. The effects are even more negative when the programme expansion is accounted for, i.e. when products entering the GS programme later than in period 26 are excluded from the sample. This specification excludes all those products (and totally new drugs) that entered the GS programme after the start of the programme. New product versions could be introduced to the market either by incumbent or entrant firms. The results suggest that the major effect comes from incumbents, since the baseline effect is virtually untouched when new firm entrants are excluded from the sample.

The findings of this subsection combined indicate the following. First, the strongest effect on pharmaceutical prices is caused by existing products getting cheaper (excluding new products makes the estimates larger). Second, price reductions for pharmaceuticals entering the GS programme later on were as strong as those for original participants (excluding programme expansion increases the effect). Third, the number of firms operating in the market seems to be is less important, which means that it is the actual behaviour of existing firms and the threat of new entrants that matter (excluding new entrant firms does not change the results). The last finding is further investigated below by estimating the effect of the reform on the number of firms selling each pharmaceutical and market concentration as measured by the Herfindahl index.

Figure 11.   Effects of programme expansion, new drugs, new product variants and new firms
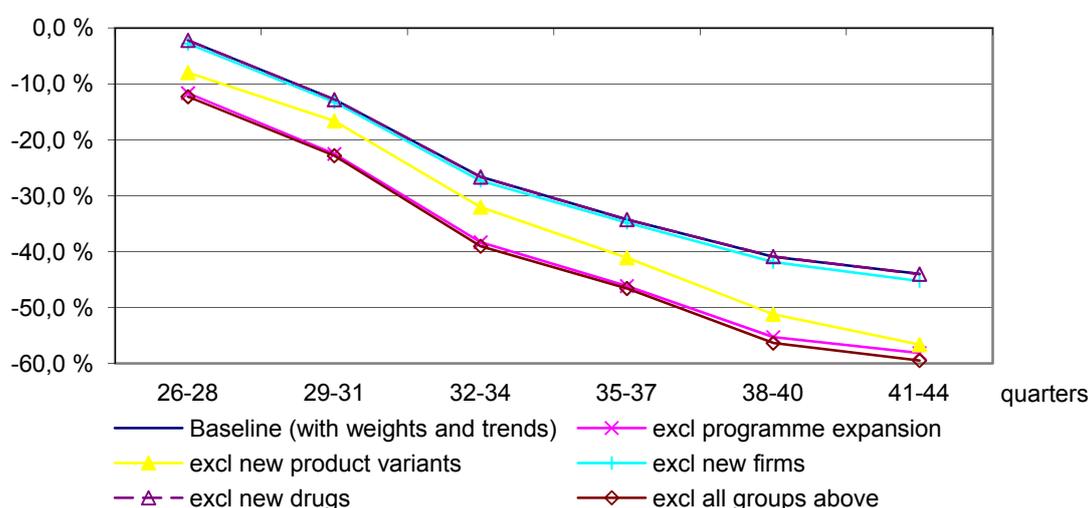
6.3 Results on market structure

A simple model regressing the Herfindahl index at the drug level on the drug level participation dummies and controls indicates that the reform intensified competition by some 10 per cent up to the 12th quarter (3 years) (Figure 12). The effect becomes lesser later on and in the last four periods (16th – 19th) it is not statistically significant any more. The estimation results of the model (1.7) are presented in Appendix 4. This is in accordance with the plain time series figures for prices above, showing that competition started easing off towards the end of the period. This model also suggests that in relative terms the effect of the reform on competition has been much milder than that on prices.

Figure 12.   *Effect of reform on drug level competition measured by the Herfindahl index*
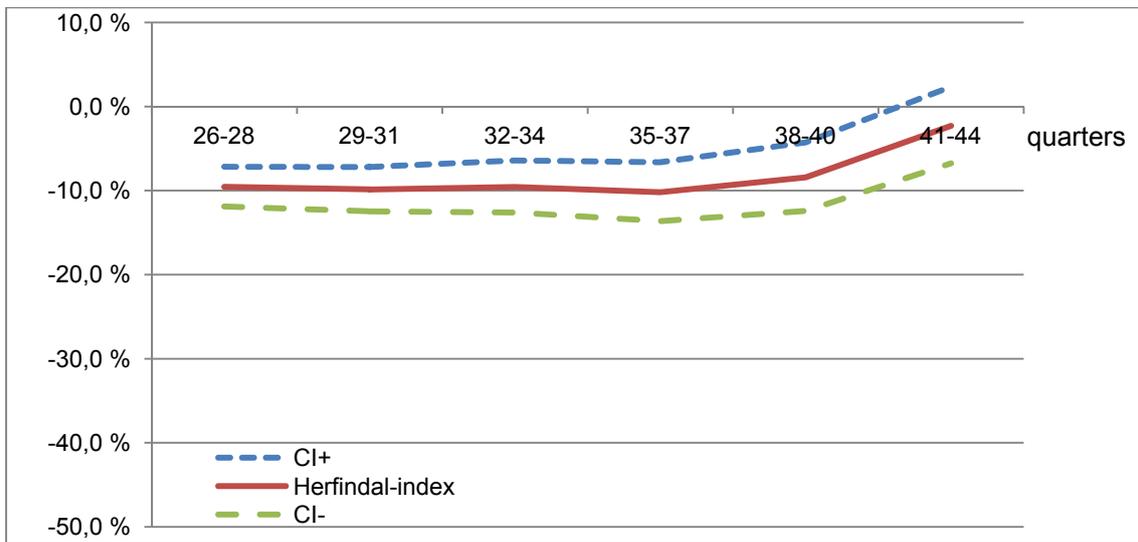
7. Discussion and conclusion

In this paper we have evaluated the price effect of the generic substitution reform in Finland. The effects are substantive and the reform was a success. The reform reduced prices and the policy effect increased over time over the whole investigation period. In 2007 the prices of GS products were 40-45% lower than before the reform. The policy had a larger effect on prices by inducing manufacturers to change their pricing strategy for existing products in the market rather than by increasing competition and the number of firms in the market.

A generic substitution policy appears to increase price information to consumers, which leads to increasing price competition, explaining the effect of the policy on prices. In order to understand therapeutic competition better, we also analysed markets with loyal and price-sensitive consumers (physicians) choosing between two quality-differentiated pharmaceuticals.

Brekke et al. (2009) show that therapeutic drugs were strategic complements for generic drugs at the 4-digit ATC level in Norwegian data, but our results do not support this finding. The prices of therapeutic drugs tended to increase clearly after generic substitution was implemented and generic price competition intensified. At the 7-digit ATC level therapeutic products are substitutes for generic products, but the observed price reactions tended to be moderate. Based on our theoretical model, one explanation for the observed differences in pricing behaviour is the proportion of loyal and price sensitive consumers. It is reasonable to assume that at the ATC-4 level, where prices tended to increase, there are far fewer price-sensitive consumers (or physicians) than at the ATC-7 level, where the risk of substitution is more obvious and the proportion of price-sensitive consumers is likely to be greater.

According to Brekke et al. (2009), so-called generic paradox results may be due to different market structures and regulatory regimes in the US compared to European countries. Danzon and Furukawa (2011) show that the prices of branded pharmaceuticals remain more or less stable after generic entry, but due to different regulatory practices price levels differ across countries. Kanavos et al. (2008) studied off-patent generic entry in the US, Canada and several European countries and found indications of generic paradox in terms of originator drugs holding their price stable after generic entry. Regan (2008) provides empirical evidence of generic paradox in US markets. In Hungary a therapeutic substitution programme (Kaló et al. 2007) did not cause expected price reductions but increased the prices of some statins.

Some theoretical and empirical models suggest that generic paradox should not be interpreted between same the active ingredients only, but should be defined in a broader sense (Stern 1996; Regan 2008; Kong 2009). Intramolecular analysis

cannot explain the generic paradox at the therapeutic level. Should this phenomenon be referred to as a therapeutic rather than a generic paradox?

Despite the increasing number of regulatory attempts, it still remains unclear how regulation affects pharmaceutical expenditure and pharmaceutical markets. There is evidence that in most cases generic substitution increases competition and cuts prices in the same active ingredient group and that a reference price system should create an incentive for consumers for switch to cheaper products. On the other hand, we observe that generic substitution may increase the prices of therapeutic competitors, which would be an undesired outcome for regulators. Being one of the possible outcomes in the market, however, such consequences should also be taken into account when designing regulatory policies like generic substitution and reference pricing.

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Legislation:

Finnish Drugs Act 1987/395

Appendix 1: Proof of Proposition

The profit function of firm 2 is defined as follows:

$$
\pi_2 = \begin{cases}
p_2\left(1-\dfrac{p_2}{q_2}\right), & \text{if } 0 \le p_2 \le \dfrac{q_2}{q_1}p_1 \\[3mm]
p_2\left[\alpha\left(1-\dfrac{p_2}{q_2}\right)+(1-\alpha)\left(1-\dfrac{p_2-p_1}{\Delta}\right)\right], & \text{if } \dfrac{q_2}{q_1}p_1 < p_2 < p_1+\Delta \\[3mm]
p_2\alpha\left(1-\dfrac{p_2}{q_2}\right), & \text{if } p_1+\Delta \le p_2 \le q_2
\end{cases}
$$

Let us denote the three parts of the profit function $\pi_m(p) \equiv p_2(1-p_2/q_2)$, $\pi_s(p) \equiv p_2[\alpha(1-p_2/q_2) + (1-\alpha)(1-(p_2-p_1)/\Delta)]$ and $\pi_l(p) \equiv p_2(1-p_2/q_2)$, where m, s and l refer to the monopoly, price-sensitive and loyal segments of the market. Direct computation shows that the profit of firm 2 is a strictly concave function everywhere and, furthermore, that the profit is a continuous function in price p_2.

We derive local maximum points for each market segment separately. Let us first consider the monopoly segment of the market. The problem of firm 2 is to maximise profit $\pi_m(p)$ subject to the constraint $0 \le p_2 \le (q_2/q_1)p_1$. Assume first that the solution of the firm's maximisation problem is an interior solution. Then it must satisfy the first-order condition

$$
1-\frac{2p_2}{q_2}=0.
$$

It is worth observing that $p_2 = 0$ cannot solve the maximization problem, because firm 2 can always increase its profit by raising p_2. By solving the above first-order condition, we obtain $p_2^{1} = q_2/2$ as an interior local maximum in the monopoly segment. Now it holds true that $p_2^m < (q_2/q_1)p_1$ if and only if $p_1 > q_1/2 \equiv p_1^{1}$. Therefore, the local maximum in the monopoly segment is $p_2^m = q_2/2$, if $p_1 \ge p_1^{1}$, and $p_2^m = (q_2/q_1)p_1$, if $p_1 < p_1^{1}$. The corresponding profit is $\pi_2^m = q_2/4$, if $p_1 \ge p_1^{1}$, and $\pi_2^m = q_2(p_1/q_1)(1- (p_1/q_1))$, if $p_1 < p_1^{1}$.

In the price-sensitive segment we analyse the Kuhn-Tucker conditions. The Lagrangian function in the price-sensitive segment is defined as follows:

$$L_2 = p_2\left[\alpha\left(1-\frac{p_2}{q_2}\right)+(1-\alpha)\left(1-\frac{p_2-p_1}{\Delta}\right)\right]-\lambda\left(\frac{q_2}{q_1}p_1-p_2\right)-\mu[p_2-(p_1+\Delta)]$$

The necessary first-order conditions of the problem are:

$$i)\ \frac{L_2}{\partial p_2}=\alpha\left(1-\frac{p_2}{q_2}\right)+(1-\alpha)\left(1-\frac{p_2-p_1}{\Delta}\right)-p_2\left(\frac{\alpha}{q_2}+\frac{1-\alpha}{\Delta}\right)+\lambda-\mu=0$$

$$ii)\ \frac{L_2}{\partial\lambda}=p_2-\frac{q_2}{q_1}p_1\ge 0;\ \lambda\ge 0;\ \lambda\frac{L_2}{\partial\lambda}=0$$

$$iii)\ \frac{L_2}{\partial\mu}=p_1-p_2+\Delta\ge 0;\ \mu\ge 0;\ \mu\frac{L_2}{\partial\mu}=0$$

Assume first that $\lambda=\mu=0$ at the solution of the maximization problem. Then from the first-order condition i) we obtain the interior solution:

$$p_2{}^s=\frac{q_2\left[(1-\alpha)p_1+\Delta\right]}{2\left[\alpha\Delta+(1-\alpha)q_2\right]} \tag{2.1}$$

Substituting the solution (2.1) into the condition ii) yields us:

$$p_1\le\frac{q_1\Delta}{\Delta+\alpha\Delta+(1-\alpha)q_2}\equiv p_1{}^2,$$

which defines the maximum value of p_1 for which the interior solution (2.1) applies. Similarly, substituting (2.1) into the condition iii) gives us:

$$p_1\ge\frac{\Delta\left[q_2-2\left(\alpha\Delta+(1-\alpha)q_2\right)\right]}{\left[2\alpha\Delta+(1-\alpha)q_2\right]}\equiv p_1{}^3,$$

which defines the minimum value of p_1 for which the interior solution applies. The maximum profit in the interior solution (2.1) is:

$$\pi_2{}^s=\frac{q_2}{4\Delta}\frac{\left(\Delta+p_1(1-\alpha)\right)^2}{\left(\alpha\Delta+(1-\alpha)q_2\right)}.$$

Let us then consider the case where $\lambda > 0$ and $\mu = 0$. From the condition ii) we then obtain the corner solution $p_2 = (q_2/q_1)p_1$. Substituting this solution into the first-order condition i) we obtain

$$\lambda = 1 - p_1 \left(\frac{\Delta + \alpha\Delta + (1-\alpha)q_2}{q_1\Delta} \right).$$

Now the condition $\lambda > 0$ implies that $p_1 > p_1^2$, which defines the set of prices for which the corner solution applies.

Consider next the case $\lambda = 0$ and $\mu > 0$. From the condition iii) we then obtain the second corner solution $p_2 = p_1 + \Delta$. Substituting the corner solution into condition i) we obtain

$$\mu = \frac{1}{q_2\Delta}\left\{ \Delta\left[q_2 - 2\left(\alpha\Delta + (1-\alpha)q_2 \right) \right] \right\} - p_1\left[2\alpha\Delta + (1-\alpha)q_2 \right].$$

The condition $\mu > 0$ implies that $p_1 < p_1^3$, which defines the set of price values for which the corner solution applies.

The case in which $\lambda > 0$ and $\mu > 0$ yields us a solution in which both constraints are binding. In such a case prices must satisfy the conditions $p_1 = q_1$ and $p_2 = q_2$. Substituting these solutions into the condition i) we obtain $\lambda = \mu + (1/\Delta)[\alpha\Delta + (1-\alpha)q_2]$, which the Kuhn-Tucker multipliers λ and μ must satisfy in the corner solution.

As the third case, we consider the loyal market segment. Firm 2 maximises profit $\pi_2^1(p)$ subject to the constraint $p_1 + \Delta \leq p_2 \leq q_2$. Assuming an interior solution for maximisation, the solution must satisfy first-order condition:

$$\alpha\left(1 - \frac{2p_2}{q_2} \right) = 0.$$

Again, $p_2 = q_2$ does not solve the maximisation problem for firm 2, because the profit of firm 2 is strictly decreasing at $p_2 = q_2$. From the above condition we obtain $p_2^1 = q_2/2$ as the interior solution in the loyal market segment. The interior solution satisfies the condition $p_2^1 \geq p_1 + \Delta$, when $p_1 \leq q_2/2 - \Delta \equiv p_1^4$. The local maximum in the loyal segment is then $p_2^1 = q_2/2$ if $0 \leq p_1 \leq p_1^4$ and $p_2^1 = p_1 + \Delta$ otherwise. The corresponding maximum profit is $\pi_2^1 = \alpha(q_2/4)$, if $0 \leq p_1 \leq p_1^4$, and $\pi_2^1 = \alpha(p_1 + \Delta)(1 - (p_1 + \Delta)/q_2)$, if $p_1 > p_1^4$.

In order to find the global maximum of the problem, we still need to compare the maximum profits at the local maximum points. Direct computation establishes

the ranking $p_1^3 < p_1^4 < p_1^2 \leq p_1^1$ between the threshold values. This implies that the global maximum point is uniquely defined by one of the local maximum points for all values of p_1 except those in the interval $[p_1^4, p_1^3]$, where one needs to compare the maximum profits at the interior solutions of the loyal and price-sensitive market segments. Now $\pi_2^s \geq \pi_2^1$, if the price p_1 satisfies the condition:

$$p_1 \geq \frac{-\Delta + \sqrt{\alpha\Delta(\alpha\Delta + (1-\alpha)q_2)}}{1-\alpha} \equiv \hat{p}_1$$

and $\pi_2^s < \pi_2^1$ otherwise. It can be shown also that $\hat{p}_1 \geq 0$, if and only if $\alpha \geq (q_2 - q_1)/q_1$.

Therefore, the best-response function of firm 2 $p_2(p_1)$ is defined as follows. Suppose that the condition $\alpha \geq (q_2 - q_1)/q_1$ holds true. Then the best response is $p_2(p_1) = q_2/2$, if $0 \leq p_1 \leq \hat{p}_1$; $p_2(p_1) = p_2^s$, if $\hat{p}_1 < p_1 \leq p_1^2$; $p_2(p_1) = (q_2/q_1)p_1$, if $p_1^2 < p_1 \leq p_1^1$; and finally $p_2(p_1) = q_2/2$ for $p_1 > p_1^1$. In case $\alpha < (q_2 - q_1)/q_1$ it holds true that $\hat{p}_1 < 0$ and the best-response function is $p_2(p_1) = p_2^s$, if $0 \leq p_1 \leq p_1^2$; $p_2(p_1) = (q_2/q_1)p_1$, if $p_1^2 < p_1 \leq p_1^1$; and $p_2(p_1) = q_2/2$ for $p_1 > p_1^1$. Q.E.D.

Appendix 2: Different drugs (active substances)

1	Acebutolol	56	Gemfibrozil	111	Perphenazine
2	Acipimox	57	Haloperidol	112	Phenobarbital
3	Alprenolol	58	Imidapril	113	Phenytoin
4	Amitriptyline	59	Irbesartan	114	Phenytoin, combinations
5	Amlodipine	60	Isradipine	115	Pindolol
6	Aripiprazole	61	Labetalol	116	Pravastatin
7	Atenolol	62	Lamotrigine	117	Pregabalin
8	Atenolol and other diuretics	63	Lansoprazole	118	Primidone
9	Atorvastatin	64	Lansoprazole, amoxicillin and clarithromycin	119	Prochlorperazine
10	Betaxolol	65	Lansoprazole, metronidazole and amoxicillin	120	Promazine
11	Bezafibrate	66	Lansoprazole, metronidazole and tetracycline	121	Propranolol
12	Bismuth subcitrate	67	Lercanidipine	122	Quetiapine
13	Bisoprolol	68	Levetiracetam	123	Quinapril
14	Bisoprolol and thiazides	69	Levomepromazine	124	Quinapril and diuretics
15	Candesartan	70	Lisinopril	125	Rabeprazole
16	Candesartan and diuretics	71	Lisinopril and diuretics	126	Ramipril
17	Captopril	72	Lithium	127	Ramipril and diuretics
18	Carbamazepine	73	Losartan	128	Ramipril and felodipine
19	Carvedilol	74	Losartan and diuretics	129	Ranitidine
20	Celiprolol	75	Lovastatin	130	Ranitidine bismuth citrate
21	Cerivastatin	76	Maprotiline	131	Reboxetin
22	Chlorpromazine	77	Melperone	132	Risperidone
23	Chlorprothixene	78	Memantine	133	Rivastigmine
24	Cilazapril	79	Metoprolol	134	Rosuvastatin
25	Cimetidine	80	Metoprolol and other diuretics	135	Sertraline
26	Citalopram	81	Metoprolol and thiazides	136	Simvastatin
27	Clofibrate	82	Metoprolol, combination packages	137	Sotalol
28	Clomipramine	83	Mianserin	138	Sulpiride
29	Clonazepam	84	Milnacipran	139	Tacrine
30	Clozapine	85	Mirtazapine	140	Telmisartan
31	Colestipol	86	Misoprostol	141	Telmisartan and diuretics
32	Colestyramine	87	Moclobemide	142	Thioproperazine
33	Diltiazem	88	Moexipril	143	Thioridazine
34	Dixyrazine	89	Molindone	144	Timolol
35	Donepezil	90	Nebivolol	145	Topiramate
36	Doxepin	91	Nefazodone	146	Trandolapril

| 37	Duloxetine	92	Nicotinic acid	147	Trandolapril and verapamil
38	Enalapril	93	Nifedipine	148	Trazodone
39	Enalapril and diuretics	94	Nilvadipine	149	Trimipramine
40	Eprosartan	95	Nimodipine	150	Valproic acid
41	Eprosartan and diuretics	96	Nisoldipine	151	Valsartan
42	Escitalopram	97	Nizatidine	152	Valsartan and diuretics
43	Esomeprazole	98	Nortriptyline	153	Venlafaxine
44	Ethosuximide	99	Olanzapine	154	Verapamil
45	Ezetimibe	100	Olmesartan medoxomil	155	Vigabatrin
46	Famotidine	101	Olmesartan medoxomil and diuretics	156	Ziprasidone
47	Felodipine	102	Omeprazole	157	Zonisamide
48	Fenofibrate	103	Omeprazole, amoxicillin and metronidazole	158	Zuclopenthixol
49	Fluoxetine	104	Oxcarbazepine		
50	Flupentixol	105	Oxprenolol		
51	Fluphenazine	106	Pantoprazole		
52	Fluvastatin	107	Paroxetine		
53	Fluvoxamine	108	Periciazine		
54	Gabapentin	109	Perindopril		
55	Galantamine	110	Perindopril and diuretics		

Appendix 3: Pre-treatment trends

To investigate differences in price trends statistically, we regress the log of price per DDD during the pre-treatment period on 157 drug dummies, 24 quarter dummies, 3 group dummies (GS for the generic substitution group and TC1 and TC2 for the therapeutic competitors groups), 3 control variables[1], and three sets of interaction terms. We have both the drug and group dummies, since not all product versions sharing the same active ingredient come under the GS programme. Sets of interaction terms model differences in trends. One set includes time dummies times the GS dummy (GS*time dummies) and the other two sets include the time dummies times a dummy for the TC1 group or time dummies times dummy for the TC2 group. We estimate the model:

$$\ln(price)_{i,t} = \phi + \sum_{d=2}^{158} \beta_d drug_d + \sum_{t=2}^{25} \chi_t time_t + \sum_{c=1}^{3} \gamma_c control_{i,t,c}$$

$$+ \sum_{t=2}^{25} \lambda_t GS_i \times time_t + \sum_{t=2}^{25} \tau_t TC1_i \times time_t + \sum_{t=2}^{25} \xi_t TC2_i \times time_t + \varepsilon_{i,t}$$

The coefficients of the interaction terms are shown in Figure A1. It appears that the prices of GS drugs slightly decrease relative to the prices in the control group. The increasing price trend of the therapeutic competitors shown above accrues from increasing prices for TC2 drugs, i.e. drugs that do not have GS drugs at the same ATC 7-digit level, only at the 4-digit level. In contrast, the price trend of the TC1 group loosely follows that of the CG group. The price trend of the TC1 drugs does not differ from that of GS drugs probably because manufacturers were aiming at getting them accepted into the GS programme. In contrast, TC2 drugs are less likely to participate, which makes it easier for manufacturers to reconsider pricing.

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[1] The control variables account for differences within drug markets, measuring the log size of package, the logged amount of DDD per product, the logged strength of a unit in a product, and the time the product has been on the market.

Figure A1. *Price trends relative to the control group before the reform.*
Weighted regression
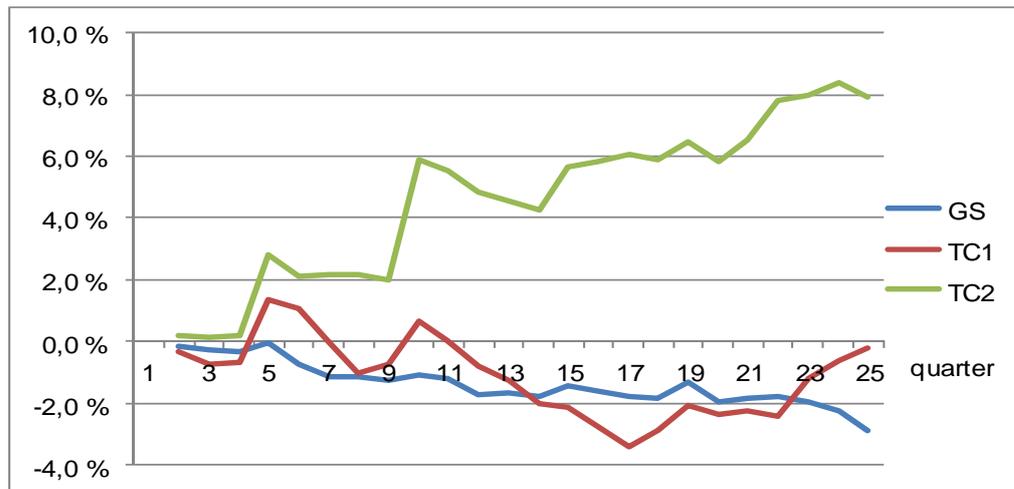
A simple F-test for the joint significance of these interaction terms shows that none of the groups jointly differ from the CG. Although none of the interaction terms is statistically significant, the price trend of the TC1 and GS groups in particular tends to deviate from that of the control group. We therefore include the price trends of the 157 drugs in the estimated equation.

Appendix 4. Results of the model (1.7)

Effect of reform on drug level competition

Dependent variable: ln (Herfindahl)

Explanatory variable	Coefficient	Std. Err.	[95% Conf. Interval]	
Participation 1	-0,1005***	0,0134	-0,1267	-0,0743
Participation 2	-0,1039***	0,0149	-0,1331	-0,0747
Participation 3	-0,1004***	0,0174	-0,1346	-0,0663
Participation 4	-0,1075***	0,0199	-0,1465	-0,0686
Participation 5	-0,0880***	0,0227	-0,1324	-0,0435
Participation 6	-0,0232	0,0238	-0,0699	0,0234
Length of stay in the market (mean)	0,0138***	0,0009	0,0121	0,0155
ln DDD per product (mean)	0,0164	0,0189	-0,0207	0,0534
ln packet size (mean)	-0,0295	0,0147	-0,0582	-0,0008
ln strength of one pill (mean)	0,0154	0,0211	-0,026	0,0568
Constant	-0,7114***	0,2568	-1,2149	-0,2079
Drug level trends	No			
Drug fixed effects	Yes, F=403,44***			
Time dummies	Yes, F=4,31***			
F-test (model sign.)	370.67***			
R^2	0.7974			
N	5173			

*** $p < 0.01$

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