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DISCUSSION PAPER

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Abstract

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In this paper we study the effects of generic substitution policy on brand-name (originator) and generic drug prices. Generic substitution policy was applied in 2003 in Finland. The Finnish framework provides a setting where only generic substitution was applied. Our theoretical model yields two different predictions for policy outcomes.

According to the first prediction, the applied policy enhances the price competition in the markets and drug prices decrease for both generic and brand name products. The second prediction suggests that the market segments and brand name products are better off by keeping prices high. In the empirical section of the article, we estimate the policy effect with quasi-natural set-up and difference in difference –framework with long term effects. According to our results, both generics and brand name products decrease prices but generic prices fall notably more than brand names.

Keywords: generic substitution, difference-in-difference, pharmaceutical prices, pharmaceutical policy

Tiivistelmä

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Työssä selvitetään 2003 Suomessa käyttöön otetun lääkevaihdon (geneerisen substituution) vaikutusta geneeristen ja alkuperäislääkkeiden hintoihin. Suomessa lääkevaihtoa on mahdollista tutkia luonnollisen eksperimentin keinoin, koska lääkevaihdon yhteydessä muut tekijät pysyivät muuttumattomina. Useissa tapauksissa lääkevaihdon yhteydessä on otettu käyttöön myös viitehintamekanismi, jolloin lääkevaihdon vaikutusten estimointi on mahdotonta. Teoreettinen mallinnus tuottaa kaksi erilaista ennustetta politiikan vaikutuksille.

Ensimmäisen ennusteen mukaan lääkevaihdon käyttöön otto lisää hintakilpailua molemmissa ryhmissä, sekä geneerisessä että alkuperäislääkkeissä. Toisessa tasapainossa ennuste on, että markkinoiden jakaantuessa alkuperäislääkkeet pitävät hinnat korkealla, eivätkä ne osallistu hintakilpailuun geneeristen tuotteiden kanssa. Empiirisessä osassa estimoidaan difference-in-difference –menetelmällä pitkän aikavälin politiikkavaikutukset hintoihin. Tulokset tukevat ensimmäistä teoreettista ennustetta: sekä alkuperäisten että geneeristen hinnat laskevat mutta geneeristen hinnat laskevat huomattavasti enemmän kuin alkuperäislääkkeiden.

Asiasanat: Geneerinen substituutio, lääkevaihto, difference-in-difference, lääkemarkkinat, lääkepolitiikka

Contents

Introduction

Spending on pharmaceuticals has been one of the fastest growing components of health care expenditures in several European countries. Average growth of per capita expenditures on pharmaceuticals reached close to 50% from 1995–2005 (Kanavos et al., 2008, Galizzi et al., 2011) and per capita average spending was EUR 349 in 2012 in the EU25 countries. Since pharmaceutical expenditures are financed mainly from the public purse (on average 73% OECD: 2012), the development has led to the implementation of cost containment measures. Cost containment instruments are variations and combinations of reference pricing systems with generic substitution (Schulenburg et al., 2011).

The aim of generic substitution (henceforth GS) is to increase consumer awareness of the available generic alternatives, substitute cheaper generic products for more expensive branded products and intensify price competition. Reference pricing (henceforth RP) has similar objectives, but the system creates stronger incentives for patients to choose cheaper alternatives than GS, since reference pricing increases patients out-of-pocket cost if the physician prescribed a more expensive drug outside of the reference price drugs. If the patient refuses substitution proposed in the pharmacy, the patient pays the price difference between the producer price and reference price.

Policy evaluation studies have focused more on reference pricing than on generic substitution (see e.g. Brekke et al., 2009 and 2011; Pavcnik 2007; Grootendorst and Stewart 2005), since in most cases generic substitution has been part of the reference pricing policy and the pure system of generic substitution has seldom been applied. Our goal is to fill this gap by examining the causal effects of a pure generic substitution policy on the prices of pharmaceuticals.

Buzzelli et al. (2006) studied the effects of the GS policy on prices and expenditures in 16 OECD countries. According to their results, the policy reduced prices by 3.1% and pharmaceutical expenditures by 1.6%, although the effect on pharmaceutical expenditures was not statistically significant. Aalto-Setälä (2008) examined the price effects of market competition after the implementation of the GS policy in Finland in a one-year period from May 2003–April 2004. His results show that the number of firms and prices are inversely related, and the price-reduction effect of the market structure is larger among expensive substitute groups than among low-priced substitute groups.

Andersson et al. (2007) and Granlund (2010) study the effects of the generic substitution reform introduced in Sweden in October 2002. Andersson et al. (2007) showed that both patients and health insurance (Pharmaceutical Benefits Scheme) benefitted from the introduction of the GS reform. The reform was associated with a significant decline in the growth rates of patients' co-payments and the subsidised costs of the Pharmaceutical Benefits Scheme. Granlund's (2010) focus is on the price and welfare effects of the Swedish GS reform. He estimated the price effects of the GS reform with an econometric model, which allows for the evaluation of the long-term effects of the policy. According to his results, the average price reduction due to the GS policy in Sweden was 10% and the effect was significantly larger for branded products than for generic pharmaceuticals. The GS reform reduced prices by 1–2% within a one-month period, while the estimated long-term reduction in prices was in the range from 6% to 17% by the end of the 2007.

Aalto-Setälä (2008) and Hokkanen et al. (2012) found contrary results to Granlund (2010) and Anderson et al. (2007). Their results showed a greater decrease of prices for generics than brand-name drugs after the implementation of the generic substitution policy in Finland. Kaiser et al. (2014) observed similar price behaviour with Danish data on statins, following a change from an external reference price system to an internal reference price.

Although the applied research in the evaluation of the pharmaceutical policies has shown significant qualitative improvement in recent years, shortcomings still exist in the literature. First, because pharmaceutical firms can adjust their pricing behaviour more freely in the long-run, studies should focus on estimating the long-term policy effects. Secondly, policy evaluations may suffer from the fact that researchers make inferences about the policy effects in an environment where several other drivers than the

ones subject to the evaluation can affect the outcome variables. In such an environment, there should be an effort to estimate the incremental policy effect of the evaluated policy.

In this paper we examine the price effects of the generic substitution (GS) policy implemented in Finland in 2003. Finland provides a good example for studying the effects of the GS policy, since the GS policy was introduced in Finland in 2003 and the reference pricing system later in 2009. Hence, the monetary incentives inducing the use of low-priced generic alternatives present in the RP system were not initially included in the Finnish generic substitution scheme. For this reason, we are able to estimate the effects of the pure generic substitution policy, while not being confounded by the previous or simultaneous policy applications.

Our theoretical section proceeds by modelling a pharmaceutical market with loyal and price-sensitive consumers (Frank and Salkever 1992) choosing between brand name and generic drugs. The fraction of price-sensitive consumers is determined by the GS policy that informs consumers about the existence of generic alternatives in the market (see Granlund and Rudholm, 2011). We derive two predictions from the theoretical model. According to the first prediction, no market segmentation occurs, and brand name products compete with generic alternatives and all prices decline. The second prediction proposes a segmented outcome. If markets segment, brand names are better off by evading price competition with generics if they can charge a high price to loyal segment consumers and generic competition becomes fierce.

In the empirical part of the study we utilize an extensive data set on prices and expenditures of prescription pharmaceuticals in Finland. Data includes 11 of the highest selling drug groups defined with a ATC level 3 (Anatomical therapeutic chemical classification, refers to 4-digit code) and cover 23 per cent of all prescription drugs in Finland. We estimate the long run price-effects of the GS policy utilizing the principles presented by Wolfers (1996). According to our results, the GS policy reduced generic prices by a quarter on average in standard two-period modelling. The long-run estimates for the overall price reduction are significantly larger, as substitutable generic prices decline by 51 per cent. The separated brand name effect is close to zero and insignificant in the standard model, whereas long-term estimates for the price decline is 31 per cent. Our estimates on the policy effects differ from estimates provided by Granlund (2010), which may be due to an application of different modelling techniques or different regulatory environments in Finland and Sweden. Regardless of our model specifications, generics decrease prices more than brand names within a substitutable drugs group.

The rest of the article is organized as follows. Section 2 describes the generic substitution policy and Finnish pharmaceutical markets. Section 3 derives theoretical predictions on the effects of the GS policy on the prices of branded and generic pharmaceuticals in a model with loyal and price-sensitive consumers. In Section 4 we describe the data, identification strategy, and econometric models that are utilized in the estimation of the GS policy effects. We utilize the difference-in-difference method with several post policy extensions. We will also display our main empirical results in Section four. We discuss the results to related studies in Section 5, while Section 6 concludes the article.

2. Finnish generic substitution system and regulation in pharmaceutical markets

A programme of generic substitution (GS) was introduced in Finland in April 2003 and a reference-pricing scheme was added in March 2009. Manufacturers were free to set the wholesale prices both before and after the 2003 reform with one notable exception. Drugs reimbursable from the National Social Insurance Scheme were subject to a price-cap regulation. The price cap (reasonable wholesale price) 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 the FPPB accepts or rejects. 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. There exist no price caps for pharmaceuticals outside the reimbursement scheme.

Price regulation is essential in the Finnish pharmaceutical market because 77% of pharmaceuticals consumed in outpatient care were subject to reimbursement in 2004 from the National Social Insurance Scheme (Timonen et al., 2005). The reimbursement ratio has declined to 64% in 2013 (Finnish statistics on medicine 2014). Pharmaceutical reimbursements are divided into three classes: the basic refund category (42% of the retail price), the lower special refund category (72% of the retail price) and the higher special refund category (100% of the retail price) in 2004.[1] The upper limit for out of pocket expenses was EUR 606.95 in 2005[2] annually. Drug purchases above that limit are fully reimbursed to patients, with only a nominal fee of EUR 1.5 fee being charged at the pharmacy.

Both the prescribing physician and the purchasing individual can decline the substitution. If the physician wants to prevent the replacement, it has to be done in advance, as pharmacists do not inform the physician if they made a replacement. The patient can decline substitution at the counter. If the patient declines the substitution, the potential saving arising from the consumption of a cheaper pharmaceutical is lost. In this respect, the denial of substitution was not costless for the patient.

There were generic alternatives in the market even before the GS reform. The generic substitution scheme obliged pharmacists to propose a substitution for a drug to patients whenever physicians prescribed a product not in the so-called price corridor. The lower boundary of the price corridor was determined by the price of the cheapest substitutable medicinal product and the upper boundary by adding a regulated margin to the cheapest price. Between 2003 and 2009,[3] the upper boundary of the corridor was determined by the cheapest price of a drug in the substitution group with an added margin of EUR 2 for products with a wholesale price of less than EUR 40. For pharmaceuticals that were more expensive, the additional margin was EUR 3. A substitutable drug was offered from products within the limits of the price corridor. The Finnish Medicines Agency (FIMEA) maintained and still maintains the list of substitutable medicinal products and updates it quarterly (Hartikainen-Herranen and Paldan, 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, while pharmacies are only allowed to add a fixed mark-up to the wholesale prices (Timonen et al., 2005). The empirical analysis in the present paper will therefore focus on wholesale prices.

1 In 2013, refund percentages decreased to 35%, 65% and 100% respectively

2 Upper annual cost limit for the patient was EUR 700.92 in 2012, EUR 670.00 in 2013, and EUR 610.00 in 2014 (Finnish statistics on medicines 2011; 2014).

3 The price corridor narrowed 4/2009, the lower group from EUR 2 to EUR 1.50 and the upper group from EUR 3 to EUR 2 margins.

3. Theoretical model

To create theoretical predictions on the effects of generic substitution policy on the prices of the pharmaceutical products, we analyse competition between a branded pharmaceutical and n generic pharmaceuticals. We assume that all generic pharmaceuticals are homogeneous and yield the same health benefit for consumers, but the quality of the branded product, s_b, differs from the quality of the generic pharmaceuticals, s_g. It is assumed throughout the article that consumers perceive the quality of the branded pharmaceutical to be better than the quality the generic pharmaceuticals and $0 \leq s_g < s_b$. The assumption on the perceived quality differences has been adopted by several researchers examining pharmaceutical markets (see e.g. Cabrales, 2003; Jelovac and Bordoy, 2005; Brekke et al., 2007). In what follows, the index $j \in \{b, g, 0\}$ makes a distinction between the branded pharmaceutical, the generic pharmaceuticals, and the outside option, and the index i = 1,2,0…,n refers to n generic pharmaceuticals.

We consider a pharmaceutical market with a heterogeneous consumer population, the size of which is normalized to one. We assume that all consumers suffer from a disease and are patients. Patients differ in terms of their willingness-to-pay for quality θ, which is assumed to follow the uniform distribution with the support in [0,1].

Following Frank and Salkever (1992), the market consists of both loyal and price-sensitive patients. The fraction of price-sensitive (loyal) patients in the market is $\Phi \in [0,1]$ $(1-\Phi)$. The fraction of price-sensitive patients Φ is determined by the generic substitution policy of the government, the role of which is to inform patients about the existence of generic alternatives and facilitate the use of generic pharmaceuticals (see Granlund 2010; Rudholm 2007).

Price-sensitive consumers have n+2 alternatives to choose from: the branded pharmaceutical with the out-of-pocket price λp_b, where λ in [0,1] denotes coinsurance, generic pharmaceutical i =1,2,…,n with the out-of-pocket price λp_i, or the outside option with no pharmaceutical consumption and zero reservation utility. All generic pharmaceuticals have the same quality and patients hence choose the one with the lowest price. The utility function of a price-sensitive patient with willingness-to-pay θ can be defined as follows

$$U^s(j) = \begin{cases} s_b\theta - \lambda p_b, \ if \ \ j = b \\ s_g\theta - \lambda p, \ if \ \ j = g \\ 0 \qquad\quad , if \ \ j = 0, \end{cases} \tag{1.1}$$

where $p = \min\{p_1, p_2, \ldots, p_n\}$.

Loyal consumers consume either the branded pharmaceutical or the outside option. Their utility function is defined as follows

$$U^l(j) = \begin{cases} s_b\theta - \lambda p_b, \ if \ \ j = b \\ 0 \qquad\quad , if \ \ j = 0. \end{cases} \tag{1.2}$$

Both branded and generic pharmaceuticals are produced at constant marginal cost c, which is assumed to be zero. This assumption has become common in the theoretical analysis of the pharmaceutical market (Brekke et al. 2007; Jelovac and Bordoy 2005; Linnosmaa 2008) due to the low variable costs of manufacturing pharmaceuticals. We examine the market environment where the branded firm is a first-mover setting the price of the branded product first, after which the price of generic pharmaceuticals is

determined in a Cournot competition between the generic firms. This modelling strategy allows us to analyse the equilibrium prices of homogeneous generic products without committing to the extreme equilibrium predictions of marginal-cost pricing and zero profits. For similar modelling strategies see Kong (2009) and Regan (2008). The profit of generic firm i = 1,2,…,n is defined as follows

$$\pi_i = p(Q,z)q_i - F, \tag{1.3}$$

where q_i is the output of generic firm i = 1,2,….,n in the market, Q is the aggregate output of n generic firms, F is a fixed entry cost, and z contains other variables affecting the inverse demand function p(Q,z). The explicit form of the inverse demand function for generic pharmaceuticals p(Q,z) will be derived in the following section. Given that generic pharmaceuticals are homogeneous, the aggregate output is defined as the sum of the supply of individual products $Q = \sum_{i=1}^{n} q_i$.

The profit function of the branded pharmaceutical is defined as follows:

$$\pi_b = p_b\left[(1-\Phi)q_b^{\,l} + \Phi q_b^{\,s}\right], \tag{1.4}$$

where $q_b^{\,l}$ and $q_b^{\,s}$ denote the demands of the branded pharmaceutical from the loyal and price-sensitive segments of the market. These demands will also be derived in the following section.

The following sections will analyse price competition between the branded and generic pharmaceuticals in order to derive theoretical predictions of the impact of generic substitution policy and market structure on prices of the branded and generic pharmaceuticals. Hence, we assume that both the generic substitution policy Φ and the number of firms (n+1firms) in the market are exogenously determined. In such an environment, we examine the following three-stage game. In Stage 1, the branded firm sets price p_b. In Stage 2, and having observed the branded price, the generic pharmaceuticals choose quantities q_i and the price of generic pharmaceuticals is realized. In Stage 3, patients choose between the alternative products available to them. We examine the subgame-perfect Nash equilibrium points for this three-stage game of perfect information.

As is typical in analysing the SPNE points of multi-stage games, we begin by analysing the final stages of the game (see e.g. Mas-Colell et al., 2005). In our case, the first task is to analyse the demands for branded and generic pharmaceuticals.

3.1 Demands for the branded and generic pharmaceuticals

In the loyal segment of the market, patients compare the utility derived from the use of the branded pharmaceutical with the reservation utility of the outside option. Let θ_{b0} denote the patient who is indifferent to both the branded product and the outside option. Such a patient can be identified by solving the equality $s_b\theta - \lambda p_b = 0$ with respect to θ. We then obtain $\theta_{b0} = (\lambda p_b)/s_b$ and $q_b^{\,l} = (1/s_b)(s_b - \lambda p_b)$, and the demand for the branded pharmaceutical in the loyal segment of the market is

$$(1-\Phi)q_b^{\,l} = (1-\Phi)\left(1 - \frac{\lambda p_b}{s_b}\right), \tag{1.5}$$

given the fraction of loyal consumers 1-Φ and a uniform distribution of the willingness to pay.

3.2 Adding price-sensitive patients

In the price-sensitive segment of the market, patients may not consume either the branded or generic pharmaceuticals for some combination of prices p_b and p. We begin the analysis by assuming that price-sensitive patients buy both the branded and generic pharmaceuticals, and after that we examine the situation in which price-sensitive patients patronize either the generic products or the branded product.

Standard results from the vertical differentiation literature (see e.g. Shaked and Sutton, 1982; Motta, 1993) apply in the price-sensitive segment of the market. Let θ_{bg} and θ_{g0} denote the marginal patients, who are indifferent to both the branded and the least expensive generic pharmaceutical and the generic pharmaceutical and the outside option, respectively. The patient θ_{bg} is identified by the equality $s_b\theta - \lambda p_b = s_g\theta - \lambda p$, which yields $\theta_{bg} = (\lambda/\Delta)(p_b - p)$ where $\Delta \equiv s_b - s_g$. Similarly, patient θ_{g0} can be found by solving the equation $s_g\theta - \lambda p = 0$, yielding $\theta_{q0} = (\lambda p)/s_g$. If the price of the branded pharmaceutical satisfies the condition (see Figure 1)

$$\left(\frac{s_b}{s_g}\right)p < p_b < \frac{\Delta}{\lambda} + p, \tag{1.6}$$

then price-sensitive patients compare the branded pharmaceutical, the least expensive of the generic pharmaceuticals and the outside option. Given the fraction of price-sensitive patients Φ, the demand for the generic products is defined as follows:

$$Q = \Phi\left(\theta_{bg} - \theta_{g0}\right) = \frac{\Phi\lambda}{\Delta}\left(p_b - \frac{s_b}{s_g}p\right). \tag{1.7}$$

The aggregate demand for generic pharmaceuticals is positive only if $\Phi > 0$. Assuming this to hold true, the inverse demand function for generic pharmaceuticals can be derived using the demand function (1.7). It is given as follows:

$$p^1 = p^1(Q, p_b) = \frac{s_g}{s_b}\left[p_b - \left(\frac{\Delta}{\Phi\lambda}\right)Q\right]. \tag{1.8}$$

Under the condition (1.6) the total demand for the branded product is given as

$$(1-\Phi)q_b^{\,l} + \Phi q_b^{\,s} = (1-\Phi)(1-\theta_{b0}) + \Phi(1-\theta_{bg}) = (1-\Phi)\left(1 - \frac{\lambda p_b}{s_b}\right) + \Phi\left[1 - \frac{\lambda(p_b - p)}{\Delta}\right]. \tag{1.9}$$

When the price of the branded pharmaceutical becomes sufficiently high, all (no) price-sensitive patients (patient) purchase(s) generic products (the branded product). The demand for the branded product in the price-sensitive segment of the market does not exist when the relative prices of the branded and generic products satisfy the condition [see Eq. (1.9)]

$$p_b \geq \frac{\Delta}{\lambda} + p. \tag{1.10}$$

Under the above condition, price-sensitive patients demand generic pharmaceuticals only. Their demand is given as $Q = \Phi(1 - \theta_{g0}) = (\Phi/s_g)(s_g - \lambda p)$. The inverse demand function for generic pharmaceuticals can then be defined as follows:

$$p^2 = p^2(Q, p_b) = \frac{s_g}{\lambda}\left(1 - \frac{Q}{\Phi}\right). \tag{1.11}$$

One should recall, however, that when condition (1.10) holds true, loyal patients are still in the market and their demand for the branded pharmaceutical is given by Eq. (1.5).

Finally, when the price of the branded pharmaceutical becomes low relative to the price of the generic pharmaceuticals and $p_b \leq (s_b/s_g)p$ (see Figure 1), all (no) price-sensitive patients (patient) purchase(s) the branded (generic) pharmaceutical. Under this condition, the demand for the branded product in the price-sensitive market segment is

$$\Phi q_b^{\ s} = \Phi(1-\theta_{b0}) = \Phi\left(1-\frac{\lambda p_b}{s_b}\right). \tag{1.12}$$

In the loyal segment of the market, patients' demand for the branded pharmaceutical is given by Eq. (1.5). Therefore, when $p_b \leq (s_b/s_g)p$, the total demand for the branded pharmaceutical is

$$(1-\Phi)q_b^l + \Phi q_b^s = 1-\frac{\lambda p_b}{s_b}.$$

Figure 1 illustrates the three price regions we have examined above. When the conditions (1.6) hold true, the price of the branded pharmaceutical is sufficiently low to attract some (but not all) price-sensitive consumers to purchase the branded pharmaceutical. In this situation the branded firm genuinely competes for price-sensitive consumers with the generic firms (Set B, Fig. 1). When the price of the branded pharmaceutical becomes very low relative to the generic pharmaceutical and $p_b \leq (s_b/s_g)p$, all price-sensitive consumers patronize the branded firm and the firm operates as the monopoly firm in both market segments (Set C, Fig. 1). In the other extreme the price of the branded pharmaceutical is so high relative to the price of the generic pharmaceuticals (Set A, Fig. 1) that no price-sensitive consumer purchases the branded pharmaceutical. Since the branded firm still serves the loyal segment of the market, we can really talk about segmented markets in this case.

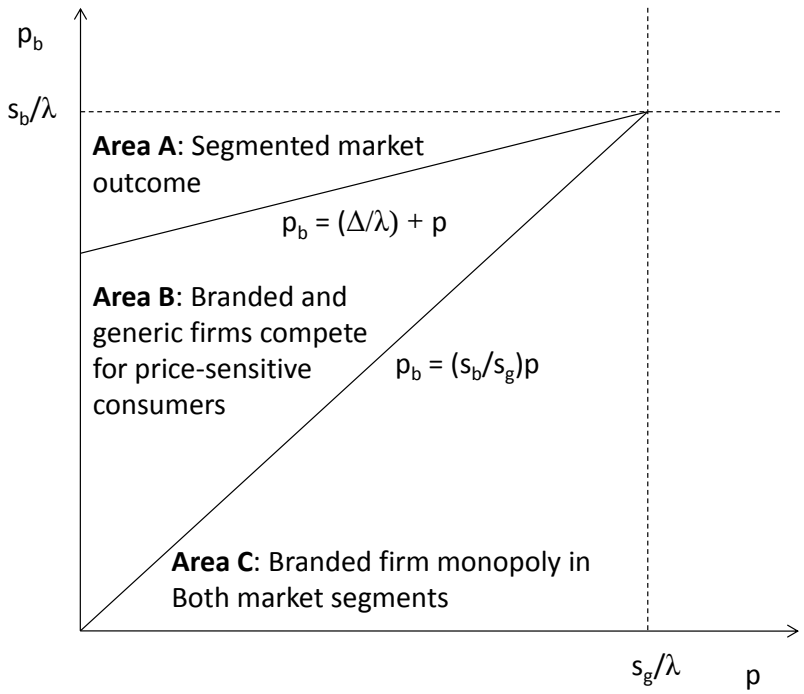


Figure 1. Prices of the branded and generic pharmaceuticals and price-sensitive market configurations

The price pairs (p_b,p) for which the monopoly profits of either or both firms become negative will be ignored in the following analysis. This happens when $p \geq s_g/\lambda$ or $p_b \geq s_b/\lambda$ or when both of these conditions are satisfied. It is not reasonable to think that the equilibrium price of the branded product or generic products would belong to either of these regions, since one of the firms always has an incentive to decrease the price in order to increase profitability.

3.3 Prices of generic pharmaceuticals

Our objective in this section is to derive a symmetric profit-maximizing price for generic pharmaceuticals. Because generic firms sell homogeneous products and there are no cost differences between the generic firms, the equilibrium price is derived by analysing symmetric Nash equilibrium points in Cournot competition between n generic firms. Reagan (2008) uses a similar approach to examine the equilibrium prices of generic products.

The above section showed that different combinations of prices p_b and p cause generic firms to face a different market environment and aggregate demand. Without loss of generality we can ignore the case where generic products face zero aggregate demand, which occurs under the condition $p_b \leq (s_b/s_g)p$ (Set C in Figure 1). There will be no price equilibrium satisfying this condition, since each generic firm has an incentive to increase its output, reduce price and capture some share of the price-sensitive market.

The following Lemma displays the symmetric profit-maximizing price of the generic pharmaceuticals for all feasible prices of the branded pharmaceutical. The proof of Lemma can be found in Appendix A1. Figure 2 illustrates graphically the price best response described in Lemma 1.

Lemma 1 The profit-maximizing price of generic pharmaceuticals is given as

$$p(p_b) = \begin{cases} \dfrac{s_g}{s_b}\dfrac{p_b}{(n+1)}, & if\ 0 \leq p_b < L \\ p_b - \dfrac{\Delta}{\lambda}, & if\ L \leq p_b \leq U \\ \dfrac{s_g}{\lambda}\dfrac{1}{n+1}, & if\ U < p_b \leq \dfrac{s_b}{\lambda}, \end{cases}$$

where

$$L \equiv \frac{\Delta}{\lambda}\frac{s_b(n+1)}{s_b n + \Delta}$$

and

$$U \equiv \frac{1}{\lambda}\left(\Delta + \frac{s_g}{n+1}\right).$$

In order to discuss the price best-response function described in Lemma 1 and the associated equilibrium points, let us first consider the case in which the price of the branded pharmaceutical satisfies the condition $p_b < L$. The best response of generic firms to the price of the branded pharmaceutical is $p(p_b) = (s_g/s_b)[p_b/(n+1)]$, and the generic firms sell the aggregate output (see the proof of Lemma 1)

$$Q^1(p_b) = \frac{\Phi n}{n+1}\frac{\lambda p_b}{\Delta}, \tag{1.13}$$

which is split equally between n generic firms in the market. Given that some price-sensitive consumers are informed about the generic products and $\Phi > 0$, the price of the branded pharmaceutical has an impact on the prices of generic products (see Lemma 1) and also on the size of the generic market. The higher the price of the branded drug, the higher are the profit-maximizing prices of generic pharmaceuticals (prices are strategic complements) and the larger is the market share of the generic products (branded and generic products are substitutes).

A second, slightly more surprising finding is that the individual generic firm's outputs and profits decrease as health insurance reimburses higher fractions of pharmaceutical expenditures and the co-payment gets smaller. This finding contradicts the usual prediction that the smaller the co-payment rate, the higher are the prices of pharmaceuticals and the profits of firms in equilibrium. In the current model a reduction in the co-payment causes price-sensitive consumers to increase the demand for the high-quality branded pharmaceutical. When the co-payment approaches zero (see Eq. (1.7)), all price-sensitive consumers purchase the branded pharmaceutical because of the quality advantage. This is the underlying reason for the non-standard result.

Let us then consider equilibrium prices and the outputs of the generic pharmaceuticals, when the condition $p_b > U$ holds true and the price of the branded pharmaceutical is high relative to the (minimum) price of the generic pharmaceuticals. In this case the price of the branded pharmaceutical is so high that no price-sensitive consumer considers purchasing the branded product. The branded firm operates as a monopoly in the loyal segment of the market and generic firms compete for market shares in the price-sensitive segment of the market. The equilibrium aggregate output of generic firms is

$$Q^2(p_b) = \frac{\Phi n}{n+1}, \tag{1.14}$$

which is divided equally between n generic firms in the market. A feature of the above equilibrium is that the price of the branded pharmaceutical has no impact on the prices or outputs of generic firms and strategic interaction between the branded and generic firms observed above no longer exists. This reflects the fact that when the market is segmented, the branded and generic firms do not compete for the same consumers.

The following figure characterizes the equilibrium prices of generic firms in the market for all feasible prices of the branded pharmaceutical.

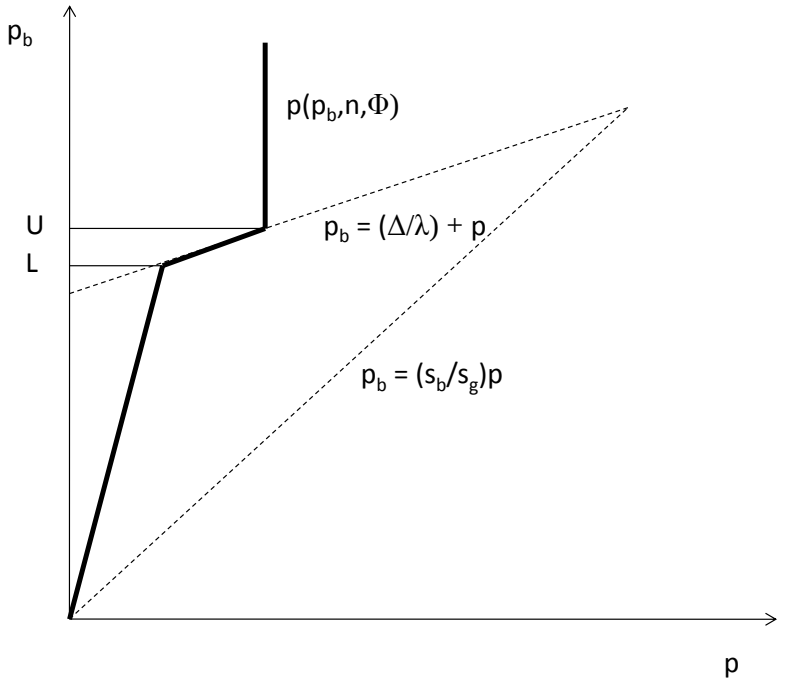


Figure 2. The price best-response function of the generic firms

3.4 Price of the branded pharmaceutical

Having described the best-response function of the generic firms, we are now ready to examine the pricing decision of the branded firm. Given symmetric equilibrium of the generic products, the reduced-form profit of the branded firm is defined as follows

$$\tilde{\pi}_b = \begin{cases} \left[(1-\Phi)\left(1-\frac{\lambda p_b}{s_b}\right) + \Phi\left(1-\frac{\lambda p_b}{\Delta}\frac{s_b n+\Delta}{s_b(n+1)}\right)\right] p_b, & \text{if } p_b < L \\ \left(1-\Phi\right)\left(1-\frac{\lambda p_b}{s_b}\right) p_b, & \text{if } p_b \geq L \end{cases} \quad (1.15)$$

The reduced-form profit (1.15) is defined into two parts. Let us denote the first and the second parts of the profit function by $v_1(p_b)$ and $v_2(p_b)$ and the unconstrained maximum points of these two functions by p_b^1 and p_b^2, respectively. The unconstrained maximum point of the first part of the profit function (see proof of Lemma 2) is given as

$$p_b^1 = \frac{s_b}{2\lambda} F(n,\Phi), \quad (1.16)$$

where

$$F(n,\Phi) \equiv \frac{\Delta(n+1)}{\Delta(n+1)+\Phi s_g n}. \quad (1.17)$$

The associated maximum profit is

$$v_1(p_b^1) = \frac{s_b}{4\lambda}\left[(1-\Phi)\big(2-F(n,\Phi)\big)F(n,\Phi) + \Phi\left(2-F(n,\Phi)\left(\frac{s_b n+\Delta}{\Delta(n+1)}\right)\right)F(n,\Phi)\right] =$$

$$\frac{s_b}{4\lambda}\left[\frac{(1+n)\Delta}{(1+n)\Delta+ns_g\Phi}\right] = \frac{s_b}{4\lambda}F(n,\Phi). \tag{1.18}$$

The above solution describes the pricing behaviour of the branded firm choosing to compete with generic firms for the price-sensitive patients. On the other hand, the monopoly price charged from the loyal consumers is the unconstraint maximum point of the second part of the profit function (see proof of Lemma 2):

$$p_b{}^2 = \frac{s_b}{2\lambda}. \tag{1.19}$$

The associated maximum profit for the branded firm is

$$v_2(p_b^2) = \frac{s_b}{4\lambda}(1-\Phi). \tag{1.20}$$

A look at the expression (1.17) reveals that $F(n,\Phi) \leq 1$, which implies that $p_b{}^1 \leq p_b{}^2$, and the branded firm choosing to compete with generic firms charges a lower price than the monopoly price the firm charged in segment markets. Lemma 2, below, describes fully when the branded firm chooses the segmented market outcome or competition with generic pharmaceuticals.

The pharmaceutical market outcome is segmented if the branded firm refrains from price competition with generic firms and charges the monopoly price from loyal consumers. The branded firm is better off doing so only if the firm's profit is higher than the profit it obtains by competing for price-sensitive consumers with generic firms and charging the price $p_b{}^1$. The proof of Lemma 2 demonstrates that the branded firm chooses the segmented market outcome if the condition

$$n(2s_g - s_b - s_g\Phi) \geq \Delta \tag{1.21}$$

is satisfied.

The condition (1.21) cannot be met if $s_b \geq 2s_g$, because the left-hand side of the equality (1.21) becomes negative while the right-hand side is strictly positive. Under this condition the profit-maximizing price of the branded pharmaceutical is (1.16). For the market outcome to be segmented, it is necessary that the quality difference between the branded and generic drugs is sufficiently small and the different versions of the drug are not too differentiated in the minds of patients. A small quality difference implies low profits from competition with generic firms and creates an incentive for the branded firm to pursue the segmented market outcome, which does not hinge on generic competition. On the other hand, if patients consider the branded pharmaceutical to be twice as good (in terms of health effects) as the generic pharmaceuticals, the branded firm always obtains a higher profit by competing with generic firms than by charging the monopoly price from loyal consumers.

If $s_b < 2s_g$, then it follows from the condition (1.21) that the market outcome is segmented if the policy parameter satisfies the condition

$$\Phi \leq \frac{2s_g - s_b - \Delta n^{-1}}{s_g} \equiv SEG(n). \tag{1.22}$$

Since any feasible generic substitution policy must satisfy the condition $0 \leq \Phi$, the other condition for the segmented market outcome is that the number of generic firms must be higher than $(2s_g - s_b)/\Delta$. Lemma 2 describes fully the profit-maximizing pricing behaviour of the branded firm. Figure 3 illustrates graphically the segmented market outcome and the situation in which the branded firm engages in price competition with generic firms in the market.

Lemma 2 *Define the set*

$$S = \left\{ (n,\Phi) \in R_+ \times [0,1] \middle| 0 \leq \Phi \leq SEG(n), n \geq \max\left\{0, \frac{2s_g - s_b}{\Delta}\right\} \right\}.$$

Then, if $s_b \geq 2s_g$, the profit-maximizing price of the branded firm is $p_b(n,\Phi) = [sb/(2\lambda)]F(n,\Phi)$ for all feasible pairs (n,Φ). If $s_b < 2s_g$, the profit-maximizing price of the branded firm is

$$p_b(n,\Phi) = \begin{cases} \dfrac{s_b}{2\lambda} & , \text{ if } (n,\Phi) \in S \\ \dfrac{s_b}{2\lambda} F(n,\Phi), & \text{otherwise.} \end{cases}$$

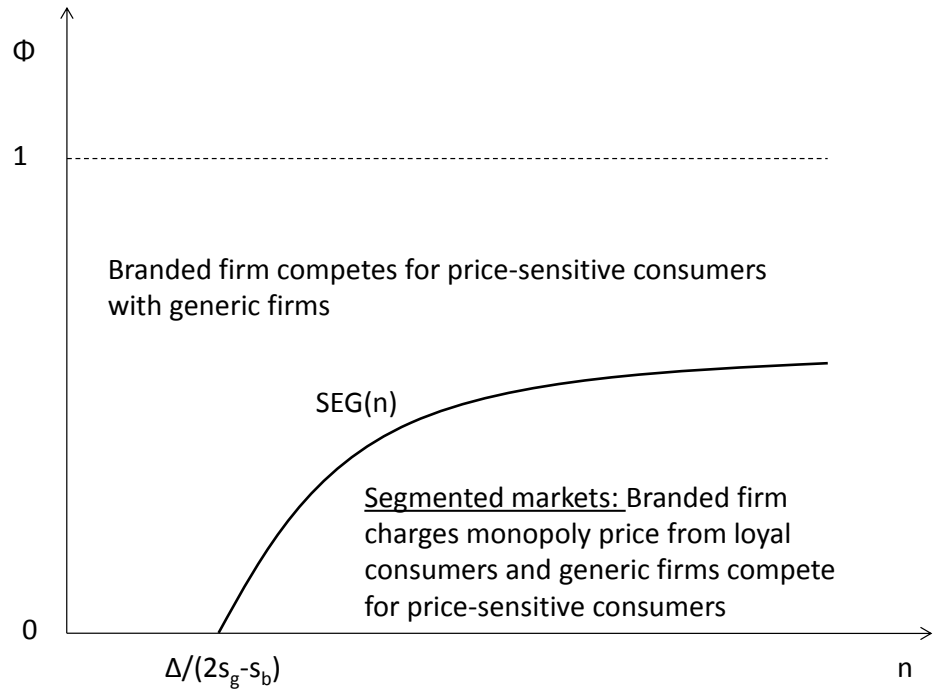


Figure 3. Market outcomes when $s_b < 2s_g$.

The above analysis suggests that the branded firm chooses the segmented market outcome if the number of generic firms is large or there are only a few informed price-sensitive consumers in the market. If there are many generic firms in the market, the branded firm is better off charging the monopoly price from the loyal

consumers, since competition with the generic products is not lucrative due to the competitive market structure. On the other hand, when the policy has succeeded to inform only a few consumers in the market, the loyal segment of the market is large and hence more profitable to the branded firm than the small price-sensitive market and competition within that market segment.

3.5 Comparative statics

The final task of the theoretical section is to provide predictions on the impact of the generic substitution policy on the prices of pharmaceuticals. For this we need to characterize the equilibrium prices of the branded and generic pharmaceuticals.

Let us first assume that the branded firm competes for price-sensitive patients with generic firms. The branded firm charges the equilibrium price $p_b(n,\Phi) = p_b^1$ (see Lemma 2), and because

$$\frac{\partial p_b^1}{\partial \Phi} = \frac{s_b}{2\lambda}\frac{\partial F(n,\Phi)}{\partial \Phi} = \frac{s_b}{2\lambda}\frac{-ns_g(1+n)\Delta}{\left((1+n)\Delta + ns_g\Phi\right)^2} < 0,$$

our model predicts that increasing the fraction of price-sensitive patients in the market decreases the price of the branded pharmaceutical. The equilibrium price of the generic pharmaceuticals in the symmetric equilibrium is

$$p_i^1 = p^1(p_b^1(n,\Phi)) = \frac{s_g}{s_b}\frac{p_b(n,\Phi)}{n+1} = \frac{s_g}{2\lambda}\frac{F(n,\Phi)}{n+1} = \frac{s_g}{2\lambda}\frac{\Delta}{\Delta + n(\Delta + s_g\Phi)} \tag{1.23}$$

Again, because

$$\frac{\partial p_i^1}{\partial \Phi} = \frac{s_g}{2\lambda}\frac{-ns_g\Delta}{\left(\Delta + n\left(\Delta + s_g\Phi\right)\right)^2} < 0$$

we have the prediction that the generic substitution policy decreases the prices of generic pharmaceuticals in the market.

The situation in the case of segmented markets is different (see Lemma 2 for specific conditions). The branded firm sets the price $p_b(n,\Phi) = p_b^2 = s_b/(2\lambda)$, which does not depend on the generic substitution policy. The equilibrium price of the generic pharmaceuticals is either $p_i^3 = p_b^2 - (\Delta/\lambda) = [1/(2\lambda)](2s_g - s_b)$ if $p_b^2 < U$, or

$$p_i^2 = p_b(p_b^2) = \frac{s_g}{\lambda}\frac{1}{n+1}, \tag{1.24}$$

if $p_b^2 \geq U$. In both cases, the equilibrium price of generic pharmaceuticals is not influenced by the generic substitution policy. The following proposition summarizes the above analysis, and the predictions will be tested in the empirical section of this article.

Proposition 1 *Generic substitution policy*

- *a) decreases the prices of the branded pharmaceutical and generic pharmaceuticals if the branded firm competes for price-sensitive consumers with generic firms, and*
- b) *has no impact on the prices of the branded pharmaceutical nor the prices of generic pharmaceuticals if the market outcome is segmented*.

Our model also allows us to contribute to the discussion about the generic paradox (Frank and Salkever, 1992), which claims that the entry of additional generic firms increases the price of the branded pharmaceutical in the market. It should be immediately clear on the basis of Lemma 2 that our model does not predict the generic paradox if the branded firm decides to compete for price-sensitive consumers with generic firms. Since we have defined that $dF/dn < 0$, the entry of additional generic firms decreases the prices of the branded and generic pharmaceuticals. On the other hand, in the case of the segmented market outcome, the branded firm charges the monopoly price to loyal consumers and the equilibrium price is independent of the number of generic firms in the market. Therefore, strictly speaking, our model does not predict the outcome $dp_b/dn > 0$. However, we do obtain the result that the monopoly price charged in the segmented market outcome exceeds the competitive price the branded firm charges when competing for price-sensitive consumers with generic firms.

4. Empirical analysis

4.1 Data description and conversions

Original data (Hokkanen et al. 2012) were provided by the Finnish Medicines Agency (FIMEA). The data set includes 51 000 observations of pharmaceutical packages in eleven different ATC (anatomical therapeutic chemical classification system) groups at the ATC level 3 (four-digit level): A02B, C07A, C08C, C08D, C09A, C09C, C10A, N03A, N05A, N06A and N06D. The original data set contains information on the name, strength, size and manufacturer of a packet, number of packages and DDDs sold, and the sales of packages in both retail and wholesale prices. Variables in the original data set are listed in Table 1.

Table 1. Variables in the original data set and descriptions

time	1997 – 2007, quarterly
substitution group	identifies a substitution group of a package
product number	unique packet identifier (trade name, packet size, form, DDD quantity)
package size	number of pills or the amount of liquid in a package
product name	trade name
strength	strength of active ingredient
active substance	-
producer	-
ATC code	standard 7-digit ATC-code
Defined daily dose (DDD)	1000 inhabitant/day, WHO standard
DDD unit	WHO standard
DDD per package	amount of DDD in a packet
retail sales in thousands (1000 €)	-
whole sales in thousands (1000 €)	-
prescription status	dispensed only with prescription
parallel trade status	sold through parallel trade

Original data span 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 due to the entry and exit of pharmaceutical products. An aggregation procedure is carried out over the whole data set, but analysis and descriptive statistics data start from 2000q1 and the timing of the policy is adjusted to 2002q4 due to the policy announcement procedure. We discuss these adjustments in more detail in the section on identification strategy and modelling.

The main variable of interest is the price of a pharmaceutical, which is measured as the price of one DDD (defined daily dose) of a pharmaceutical product during 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). The price variable is computed for each package in the original data set and deflated with the consumer price index.

Instead of using package-level information to examine markets, we aggregated information on pharmaceutical packages to the level of pharmaceutical products, defined by active ingredients, trade

names and manufacturers. For instance, Zocor manufactured by Merck Sharp & Dohme BV is defined as a product. The product-level DDD-price is formed by weighting the price of a package by the number of packages sold. After aggregation, we have 10 651 product-level observations in the data set, 126 active ingredients defined at the ATC level 5 (first seven digits), and 481 unique products. Brand name products in the data were identified using information obtained from the Finnish Medicines Agency. Identification data was not complete and some additional searches from internet databases had to been done. Our data set contains 163 brand name products.

Outlier observations were excluded from the original data set. All liquid-form drugs, products of combined substances, and undefined packet sizes or dosage strengths were excluded as these were not valid for aggregation due to different dimensions (for example, a product strength measured in ED-unit). After aggregation, all product-level observations with less than one-year appearances in the market were excluded. Products can enter and exit the markets only once. Nine active substances in the ATC level 5 codes (7 digits) were excluded due to their entry after the 26th quarter for not violating the common trend assumptions. Exclusions are detailed in Appendix A2.

Our data set allows natural definitions of the treatment and control groups to be used in the policy analysis. The treatment group (GS group) consists of 313 substitutable products, and a product is defined to the GS group if it becomes substitutable within any period after the implementation of the generic substitution policy in 2003. We define an aggregated product to be substitutable whenever the first package of the product becomes substitutable. The Finnish Medicines Agency updates the list of substitutable packets quarterly.

The therapeutic competitors (TC) group contains 205 products that are non-substitutable over the whole observation period, but belong to the same level 3 ATC groups (first four digits) with substitutable products. Therapeutic classification is needed to control for the possible cross-price effect from the treatment group (see Brekke et al., 2009). Active substances in the TC group have been developed to treat the same medical conditions as those in the GS group, but pharmaceuticals in the group are not part of the GS programme. Defining the TC group with the first four digits of ATC code allows for the fact that, for example, different statin substances in C10A may be therapeutic substitutes for each other if their cross-price elasticities are positive. One reason for being a therapeutic competitor is that no similar strength drug exists in the market that generic substitution would require, or that it may be under patent.

The control group (CG) is formed of those pharmaceuticals that never become substitutable within the study period and do not have therapeutic competitors (TC-group drugs) at the ATC code level 3. In practice, the control group consists of 11 products in the C08D class in our data set. Outlier modifications decrease the number of observations in the control group, leading eventually to complete exclusion of the products belonging to the C07F group. The N03A group contains non-substitutable products, but those are heavily exposed to therapeutic competition and were therefore not included in the control group.

We defined a pharmaceutical market to consist of products belonging to the same at ATC level 5 -group, which refers to the active ingredient level. There is some empirical evidence supporting the argument that different active ingredients may belong to the same market (see (Brekke et al., 2009; Ellison et al. 1997) and that therapeutic competition exists. According to our definition, competition takes place among products in the same ATC level 5 for the following reasons. Firstly, we are not able to identify when products with different active ingredients would be competitors – it depends greatly on a patient's diagnosis and proposed treatments by physicians. Secondly, generic substitution policy takes place at pharmacies, where products compete at the ATC level 5 or even at a more refined level in practice. Therefore, a somewhat narrower definition of a market is justified.

Table 2 sums up the descriptive statistics before, after and overall on aggregated data according to the main groups defined earlier. Before and after figures indicate that, on average, GS-group drug prices decreased after the generic substitution policy was implemented. Control-group prices remained quite stable. Therapeutic competitors raised their prices on average within the study period.

Table 2. Product-level regressed DDD real prices (xEUR 1000) over main groups.

Before generic substitution policy (2000q1 – 2002q3)					
	Obs.	Mean	robust S.E.	95% CI	
GS group	1105	0.00665	0.0000175	.0066189	.0066875
TC group	1158	0.00689	0.0000103	.0068692	.0069096
Control group	110	0.00364	0.0000074	.0036287	.0036579
After generic substitution policy (2002q4 – 2007q4)					
GS group	4060	0.00452	0.0000189	.0044794	.0045535
TC group	1738	0.00893	0.0000619	.0088093	.0090523
Control group	182	0.00336	0.0000342	.0032953	.0034305
Over the study period (2000q1 – 2007q4)					
GS group	5165	0.00497	0.0000189	.0049365	.0050107
TC group	2896	0.00811	0.0000452	.008026	.0082031
Control group	292	0.00347	0.0000347	.0034137	.0035233

4.2 Identification strategy and modelling

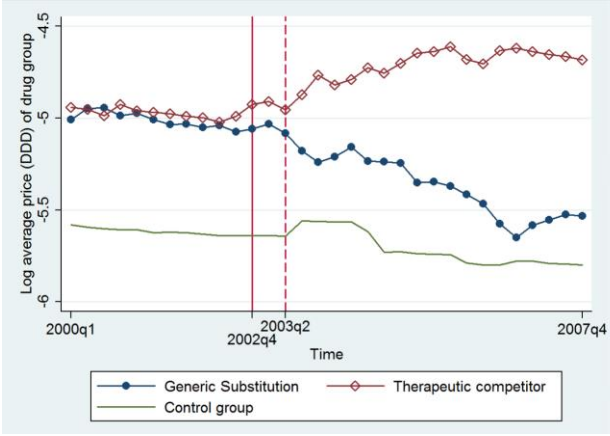
Our main objective is to estimate the average treatment effects (ATEs) of the generic substitution policy by applying a differences-in-differences setup. Applied pharmaceutical policy in Finland provides us with an environment that can be analysed in a quasi-natural experimental framework (Angrist and Lavy 1999, 2002). Gradual implementation of the generic substitution and reference pricing policies ensures that no previous policies or regulation, except the price cap regulation, affects the outcome. Price regulation should not affect price competition; it only defines a maximum wholesale price of pharmaceuticals through negotiation with the FPPB. This provides us a setup where the price effects of the GS policy can be estimated.

Traditionally difference-in-differences estimation is built on the following key assumptions for ATE-interpretation: i) the populations of interest have common trends in pre-policy periods and ii) selection does not affect populations in the treatment and control groups (Blundell and Costa-Dias 2009).

Figure 4a displays the average prices in the main groups of interest both before and after the implementation of the policy. The vertical dashed x-line in both figures 4a and 4b point to the time of introducing the policy in the 2nd quarter of 2003. The solid x-line in the figures refers to the announcement of the government proposal in the fourth quarter of 2002 (HE 165/2002) for applying generic substitution. We assume that the policy began to influence firms' pricing behaviour already at the time the government proposal was announced and therefore define the intervention as beginning in the fourth quarter of 2002.

Figure 4a reveals that no discernible differences in the price trends between treatment, control and therapeutic groups exist in the pre-policy period. In Figure 4b additional logarithmic DDD-prices of substitutable generics and substitutable brand name products are displayed, which refines our estimation strategy and allows the separate estimation of the policy on prices for branded products.

4a Main drug groups



4b substitutable and brand-name drugs subject to policy

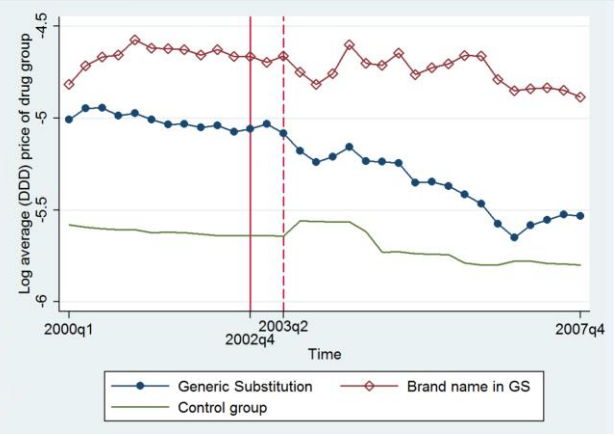


Figure 4. Average prices before and after the implementation of the generic substitution (GS) policy.

We test the validity of the common-trends assumption by estimating the price trends for the treatment and control groups over the pre-policy periods from the first quarter of 2000 to the third quarter of 2002. Results are displayed in Table 3. The logarithmic DDD-price was regressed for all products and the branded products in the treatment group on interaction with the GS group, time trend, therapeutic competition dummy variable, number of generic firms and product-level fixed effects. This modelling follows the strategy of an actual policy effects estimation.

Standard errors are clustered at the active substance level (ATC Level 5) yielding us 109 clusters for estimations. We assume the product prices correlated within active ingredient levels. Due to the applied policy, we do not take into consideration the dependencies between therapeutic substitutes (4-digit code, ATC Level 3), even if this might exist (Angrist and Pischke 2009; Pavcnik 2002). With product-level clustering we would neglect the possibility of a correlation between products that are produced from an identical active ingredient. Pre-treatment trends were not valid when the test period was pro-longed to the first quarter of 2003, i.e. to the time of actual intervention

Table 3. Pre-treatment trend test 2000q1 – 2002q3

	Interaction groups in model	
	substitutable drugs	brand x substitutable
Interaction 2000q1	0.000264	0.00360
	(0.00300)	(0.0130)
Interaction 2000q2	-	0.00694
		(0.0111)
Interaction 2000q3	0.00129	0.00469
	(0.00281)	(0.0107)
Interaction 2000q4	-0.00372	0.0102
	(0.00451)	(0.00970)
Interaction 2001q1	-0.0122*	0.0218*
	(0.00698)	(0.0117)
Interaction 2001q2	-0.00872	0.00770
	(0.0111)	(0.00886)
Interaction 2001q3	-0.0180	0.00494
	(0.0119)	(0.00952)
Interaction 2001q4	-0.0211*	0.00770
	(0.0109)	(0.00843)
Interaction 2002q1	-0.0300**	0.0100
	(0.0146)	(0.00968)
Interaction 2002q2	-0.0319**	0.00864
	(0.0140)	(0.00934)
Interaction 2002q3	-0.0326**	0.00371
	(0.0147)	(0.00926)
Joint significance of interactions (prob > F)	0.1753	0.2486
F-stat.	F(10, 108) = 1.43	F(11, 108) = 1.27
Therapeutic	-	
Number of generic firms in market	-0.000817	
	(0.00223)	
Fixed effects	Yes	
Time-dummies	Yes	
Observations	2,373	
Number of products	245	
R-squared	0.130	
F-test	66.91***	

Clustered robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The data for the study are based on the most common diagnoses and the largest drugs classes where generic substitution occurs. The chosen ATC classes cover 23.5 per cent of all reimbursed pharmaceutical expenditures. Based on the above test results on common pre-policy trends, the ATE-interpretation of the policy effects is internally valid for the included drug groups. As for external validity, however, we cannot argue that the estimated policy effects would apply to all substitutable products on average. We merely assume that the resulting estimates represent upper bounds for the policy effects due to the use of the most common ATC groups exposed to the GS policy. We expect that smaller ATC-groups would imply smaller markets but also smaller policy effects.

The control group has to meet the requirements of parallel trends and similarity in observables, but it must not be affected (contaminated) by the applied GS policy. Data contain several ATC groups that are not subject to policy and the active substances are similar in the observables to the treatment group. Forming a control group of all the ATC groups that meet this criterion would in principle provide a good control group. The downside of using such a control group is that it may generate a bias through therapeutic competition (Pavcnik 2002; Brekke 2009). Excluding the therapeutic substitutes with an ATC 4-digit code (ATC Level 3) leaves us with a control group that consists of C08D-class pharmaceuticals only. Such a control group avoids selection bias with the treatment group. The exclusion decision is made on the basis of medical treatment safety for the selected groups. Drugs in C08D are mainly used to treat arrhythmia, and the Finnish Medicines Agency excluded those pharmaceuticals from the substitution program (Hartikainen-Herranen and Paldán 2005).

Restricting the control group may raise the question of whether the defined control group provides a good reference for all ATC-groups subject to the policy. It may apply better to C-group drugs, but they are less similar to ATC A- or N-group drugs. This links back to the feature discussed above: the control group formed from the most similar in observables observations -rule is not plausible without generating a therapeutic bias into estimates.

We can evaluate the plausibility of the actual control group (CG) with a therapeutic group (TC) in pre-policy periods. The TC group does not differ from the control or treatment groups before the GS policy is applied and it includes the same active ingredients as the treatment group by definition. Pre-treatment tests are not jointly significant for therapeutics (Prob > F = 0.5610) when regressed with a substitutable and control group. We argue that the TC group can be seen as a second control group in the pre-policy period with more observations, while the actual control group (CG) does not differ from other groups. Our understanding is that therapeutic bias in control group prices is a more severe problem for the ATE estimation than the less valid control over all pharmaceuticals.

The number of firms in the control group declines from six in the first period to four in the 27th period and remains unchanged for the remaining study periods. These changes do not have severe impacts on DDD-prices in the control group (see Figure 4). However, regulatory changes in maximum prices can change prices exogenously: for instance, an FPPB-applied price reduction (via a renewed sales permit) for C08D products in the 4th quarter of 2004, which can be observed and controlled in our data. In addition, an FPPB decreased the maximum accepted wholesale price by 5 per cent in 2006 for all prescription products (government proposal 97/2005). This does not require additional measures, as all products were affected.

If we have reason to assume that policy effects adjust or change over time, a multi-period extension of the two-period DID-model offers more insight into price variations over time (Wolfers 2006; Wooldridge and Imbens 2009). On the basis of Figure 4 such price variation is evident. It took some time for the price effect to adjust after the policy was implemented. A long-term price adjustment is also emphasized by Granlund (2010) in his study on the effects of the generic substitution policy.

With the above arguments we assume causality from the generic substitution policy to prices in models without controls for market structure. Controlling the market structure may also create a problem of bad controls if the market structure itself is influenced by the policy (Angrist and Pischke 2009). We estimate the models with and without market structure and evaluate the difference between the obtained estimates.

4.3 Econometric models

Econometric modelling is done in two steps. We first estimate a standard DID-model where the differences in the mean outcomes between the treatment and control groups are compared after and before the government announcement of the forthcoming policy. We then extend the standard setup to a multi-period model, which allows an estimation of the policy effects over time. In both steps, we also include the number of generic firms into the analysis in order to control for any effects that market structure might have on the prices of pharmaceuticals. Although we acknowledge that market structure may be

endogenously determined, we proceed with the OLS-estimation with no aim to give a causal interpretation for the parameter estimate associated with the number of generic firms.

Equation 2.1 below displays the baseline econometric model. The model is similar to Brekke et al. (2009) or Pavcnik (2002). The dummy variable GS identifies those products that were subject to generic substitution at some quarter after the government proposal in October 2002. The policy was applied in April 2003 for pharmacies and became observable to consumers. The reason for the adjustment is that firms may respond to the announcement of a forthcoming policy and pre-trend tests support this adjustment. The parameter *β1* estimates the average price effect of the GS policy for all substitutable pharmaceuticals, and the parameter *β1+β2* for the substitutable brand-name products (BRAND-variable identifies brand name products). The dummy variable TC controls for therapeutic competitors and the interaction BRAND×TC brand-name products in TC price effects in the post-policy period. Therapeutic competitor is defined at the same ATC level 3 with substitutable products but TC's never are substitutable. The variable NoFg_{mt} measures the number of generic firms in the market *m* at time period *t*. This variable was introduced to control the effect of market structure on the prices of pharmaceuticals. We define a pharmaceutical market as including all products with the same active ingredient. The product-level fixed effects were included as controls of time-invariant unobserved heterogeneity over different products. Time dummies τ_t were introduced to control time trends, interaction τ_t ×ATC 3-digit controls state-specific trends for robustness and ε_{it} is the error term.

$$\ln p_{it} = \beta_1 GS_i + \beta_2 BRAND_i \times GS_i + \beta_3 TC_i + \beta_4 BRAND_i \times TC_i + \beta_5 NoFg_{mt} + \tau_t + \alpha_i + \varepsilon_{it} \quad (2.1)$$

We then utilize a multi-period extension of the model (2.1) following the ideas presented by Wolfers (2006) and applied earlier to Finnish data by Hokkanen et al. (2012). Compared to two-period DID-estimation (see e.g. Wolfers 2006; Wooldridge and Imbens 2009), the division of the post-policy period into sub-periods allows us to explore the effects of the policy over time. The multi-period model is formalized as follows:

$$\ln p_{it} = \sum_{j=1}^{7} \theta_{0j} GS_{ij} + \sum_{j=1}^{7} \theta_{1j} GS_{ij} \times BRAND_i + \beta_1 TC_i + \beta_2 BRAND_i \times TC_i + \beta_3 NoFg_{mt} + \tau_t + \alpha_i + \varepsilon_{it} \quad (2.2)$$

In the above model (2.2), the variable GS_{ij} is a dummy variable obtaining value 1 if product i is subject to generic substitution for j sub-periods after the government proposal of the policy. Products with the highest values of GS_{ij} belong to the generic substitution programme from the beginning of the program until the end of the study period (see Hokkanen et al., 2012).

The post-policy periods, quarters 24–44 (2002, 3rd quarter – 2007, 4th quarter), are divided into seven sub-periods. The first sub-period after the generic substitution proposal (ie. j = 1) refers to the two quarters 24–25 and the second sub-period to quarters 26–28 (ie. j = 2), emphasizing that the substitution policy is active from the 26th quarter onwards. The third sub-period refers to quarters 29–31, the fourth to quarters 32–34 and so on until the seventh sub-period refers to the last quarters 41–44 in our data. The multi-period model allows us to estimate the average price change caused by the GS policy separately for each sub-period and for both generic and branded products.

In the multi-period model 2), the parameter θ_{0j} estimates the effects of the policy for generic products in the group of substitutable products in the sub-period j=1,2,…7, and the sum $\theta_{0j}+\theta_{1j}$ measures the policy effects for substitutable brand-name products. Policy effects are estimated for seven separate time periods after the implementation of the policy. The control variables are otherwise the same as in the first model.

The propositions for pricing behaviour derived in the theoretical section are tested with models (2.1) and (2.2) described above. Our theoretical model predicts that the GS policy leads to price reductions for both generics and branded drugs if no segmentation occurs. On the other hand, if market segmentation takes place, the policy is ineffective for branded firms. Generic firms compete in price with each other, and

the brand names refrains from price competition. This can take place if the policy aiming to inform patients about the existence of generic products does not reach many patients or if generic competition is fierce.

4.4 Empirical results

We first estimate four variants of the standard model, which refers to two-period differences in differences (DID). The estimation strategy follows that outlined by Brekke et al. (2009). Results and model variations are displayed in Table 4.1. The estimate of the standard DID-parameter β_1 -0.323 (model 1 in Table 4) implies an average 28 per cent price reduction (Log – level conversion) for substitutable drugs after the announcement of the proposal. The estimated coefficients remain stable after adding control variables to the baseline model and the results remain the same qualitatively for all models. The price effects of the policy for the substitutable branded products differ from the average generic price effects (model 2 and model 3 results in Table 4) as branded prices decrease less than generics.

Including therapeutic controls decreases the substitution effect and the results are in line with the predictions of the segmented markets model (see Section 3), as tested coefficients $\beta_1+\beta_2$ are zero for substitutable brand-name products. Therapeutic brand-name products also have a separate and significant positive effect in the group of therapeutic competitors (model 3 results in Table 4). The therapeutic group consist of non-substitutable and new products that may be under patent. These reasons can drive increasing prices in the therapeutic group.

Full model results are displayed in the model 4 column, with an exogenous number of generic firms. The generic products price effect due to policy is -23%, whereas the substitutable brand names combined price effect is close to zero and not significant. In other words, brand names do not respond to applied policy. The effect of the number of generic firms is significant and negative. However, the number of firms has an effect mainly on generic prices, but we underline that this is not a real market structure effect. State-specific trend results are displayed in the model 5 -column for a robustness check. These support other results on the segmented outcome of prices due to the applied policy. The state-specific trends specification (model 5) results are close to model 4 as they can include the market structure effect within it.

Table 4. Price effects for generic substitution

	model(1)	model(2)	model(3)	model(4)	model(5) with state x time
VARIABLES	ln price/DDD	ln price/DDD	ln price/DDD	ln price/DDD	ln price/DDD
Substitutable drugs	-0.323***	-0.480***	-0.340***	-0.259***	-0.263***
	(0.0679)	(0.104)	(0.0947)	(0.0885)	(0.0720)
Brand x Substitutable		0.281***	0.289***	0.279***	0.268***
		(0.0884)	(0.0887)	(0.0844)	(0.0786)
Therapeutic			0.0254	0.0286	0.0276
			(0.0376)	(0.0378)	(0.0523)
Brand x Therapeutic			0.160***	0.152***	0.157***
			(0.0478)	(0.0458)	(0.0475)
Number of generic firms in the market				-0.0609***	
				(0.0160)	
Observations	8,353	8,353	8,353	8,353	8,353
R-squared	0.367	0.383	0.386	0.424	0.493
Number of product id	444	444	444	444	444
FPPB	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
Time-dummies	Yes	Yes	Yes	Yes	Yes
F-test	8.81***	8.96***	NA	NA	NA

Cluster robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The estimation results of the multi-period extensions (model 2.2) are displayed in Table 5. The first period's price effect is tested zero and significant price reductions occur in the last six periods. The fact the first period is not significant for both types, generics and brand names, is due to the applied policy that becomes active in pharmacies after the 2nd quarter of 2003 (quarters 26–28).

Adding the number of firms to the model shows (model 7 in Table 5) that, as generally assumed, the increasing number of firms has a significant and negative impact on prices and the main effect does not depend on the model specification. However, by adding the number of firms into the model, we assume that the number of generic firms is exogenously determined. Adding the number of generic firms so as to control for the market structure shifts some of the effect from the policy's price reduction. For all substitutable drugs, the first and second period estimates are insignificant, while substitutable branded drugs in the first three periods yields a tested zero effect. Long-term effects for both types yield price reductions in the substitutable group, being notably greater for generics than for brand-names. This supports the theoretical prediction for proposition 1 in the standard case, where markets do not segment.

Table 5. Price effects for generic substitution in multi-period estimations

	model (6)	model (7) No. of generic firms	model (8) with state x time	model (9) with state x time and No. of generic firms
VARIABLES	ln price/DDD	ln price/DDD	ln price/DDD	ln price/DDD
Substitutable drugs (24-25 quarters)	0.000654	0.0456	0.0595	0.0766
	(0.0924)	(0.0824)	(0.0556)	(0.0570)
Substitutable drugs (26-28 quarters)	-0.224**	-0.142	-0.132**	-0.0774
	(0.102)	(0.0948)	(0.0557)	(0.0631)
Substitutable drugs (29-31 quarters)	-0.443***	-0.348***	-0.330***	-0.258***
	(0.105)	(0.0986)	(0.0638)	(0.0725)
Substitutable drugs (32-34 quarters)	-0.640***	-0.546***	-0.510***	-0.437***
	(0.116)	(0.108)	(0.0779)	(0.0842)
Substitutable drugs (35-37 quarters)	-0.719***	-0.633***	-0.578***	-0.510***
	(0.120)	(0.113)	(0.0892)	(0.0947)
Substitutable drugs (38-40 quarters)	-0.764***	-0.686***	-0.616***	-0.551***
	(0.143)	(0.136)	(0.117)	(0.121)
Substitutable drugs (41-44 quarters)	-0.844***	-0.775***	-0.721***	-0.653***
	(0.172)	(0.165)	(0.147)	(0.148)
Brand x Substitutable (24-25 quarters)	-0.0114	-0.0322	-0.0346	-0.0489
	(0.0697)	(0.0645)	(0.0523)	(0.0501)
Brand x Substitutable (26-28 quarters)	0.162*	0.117	0.138**	0.0964
	(0.0902)	(0.0874)	(0.0676)	(0.0696)
Brand x Substitutable (29-31 quarters)	0.316***	0.284***	0.285***	0.253***
	(0.102)	(0.0972)	(0.0888)	(0.0881)
Brand x Substitutable (32-34 quarters)	0.401***	0.387***	0.360***	0.345***
	(0.0980)	(0.0927)	(0.0907)	(0.0894)
Brand x Substitutable (35-37 quarters)	0.414***	0.428***	0.374***	0.388***
	(0.0973)	(0.0945)	(0.0956)	(0.0938)
Brand x Substitutable (38-40 quarters)	0.386***	0.424***	0.357***	0.396***
	(0.129)	(0.127)	(0.122)	(0.120)
Brand x Substitutable (41-44 quarters)	0.375**	0.427***	0.354**	0.408***
	(0.149)	(0.149)	(0.138)	(0.137)
Therapeutic x policy	-0.0338	-0.0263	-0.0141	-0.0128
	(0.0289)	(0.0304)	(0.0406)	(0.0435)
Brand x Therapeutic x policy	0.0672*	0.0665*	0.0842**	0.0747**
	(0.0346)	(0.0343)	(0.0398)	(0.0367)
Number of generic firms in market		-0.0527***		-0.0530***
		(0.0150)		(0.0144)
Observations	8,353	8,353	8,353	8,353
R-squared	0.491	0.518	0.562	0.585
Number of product id	444	444	444	444
Fixed effects	Yes	Yes	Yes	Yes
Time-dummies	Yes	Yes	Yes	Yes
State x time	No	No	Yes	Yes
FPPB	Yes	Yes	Yes	Yes
F-test	NA	NA	NA	NA

Cluster robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Percentage changes of prices are displayed in Table 6. Standard DID results are converted from the model 3 (Table 4) specification and with the *state x time* trend from model 5. The generic price reduction varies from -23 to -29 per cent between specifications. The average policy effect may be underestimated in model 2.1 if the long-run effect on prices is 51 to 57 per cent lower after the government proposal. Long-run coefficients are log-level converted from multi-period specifications model 6 and model 8 in Table 5.

Brand names have a tested zero average effect in the standard DID models but as emphasized earlier, results are refined in the multi-period estimation. Results for brand name price effects are from the same specification as for the generics above. Significant and tested price reductions occur from the second to seventh periods, quarters 26–44. Including the *state x time* trend yields a tested zero effect for brand names in quarters 24–31 and from 32 onwards the effect is negative and significant. No specification yielded a greater price reduction for brand names over generics.

Table 6. Policy effect on branded and generic prices in per cent

	Generics		Brand-name	
state x time trend	No	Yes	No	Yes
Standard DID models	-29 %***	-23 %***	0 %	0 %
multi-period models				
24–25 quarters	0 %	6 %	-1 %	3 %
26–28 quarters	-20 %**	-12 %**	-6 %*	1 %
29–31 quarters	-36 %***	-28 %***	-12 %***	-4 %
32–34 quarters	-47 %***	-40 %***	-21 %***	-14 %***
35–37 quarters	-51 %***	-44 %***	-26 %***	-18 %***
38–40 quarters	-53 %***	-46 %***	-31 %***	-23 %***
41–44 quarters	-57 %***	-51 %***	-37 %***	-31 %***

5. Discussion

According to our results, brand name drugs do not respond to increased generic competition in standard two-period DID modelling in our data at first glance. Model 2, where the therapeutic effect is excluded, shows decreasing prices for both brand name and generics, but as stated earlier, the therapeutic effect can bias the results. Estimates with the therapeutic group provided falling prices for substitutable generics and only a minor reduction for substitutable brand names. In coefficient tests for model 3, the brand name-effect was not statistically significant. An exogenous interpretation for the market structure decreases the price effects of policy.

The long-run effect estimation with several post-policy periods refines the standard modelling results. For a post-policy period of almost five years, it is useful to study the price effect changes over time. Long-term effects in our study confirm that both prices do decline, but that the brand-name price reductions are notably smaller than for generics due to the applied generic substitution policy. The eventual price reduction can be very different depending on the modelling strategy, as the generic prices fall between 51–57 per cent and the brand names fall 31–37 per cent according to the multi-period estimates. The gap to our standard model results is close to 30 per cent. It is rational to assume that standard modelling cannot capture the effect as accurately as estimating several post-policy periods does. Long-run effects are in line with the theoretical prediction of the standard case in proposition 1. The results remain robust and qualitatively the same for all model variants. Our results accord with the study by Aalto-Setälä (2008), where generics and brand-name products have different price effects in the Finnish data.

A limitation regarding our results is that we estimate an upper boundary for the policy effect because our sample consists of the highest selling pharmaceuticals, which here consists of 23 per cent of all reimbursable drugs in Finland. For DID-identification the validity of our control group may raise concerns as it consists of the ATC class of C08D drugs only. We showed earlier in the identification section that the control group fulfils the common trends requirements with and without therapeutic substitutes in the pre-policy period. An improvement would be to estimate the policy effect with an increase in all pharmaceuticals. Depending on the model variation, the brand name price reduction comes with a long lag time, which may indicate that some unobserved feature can push prices downwards, other than the policy itself, i.e. endogenous market structure effects, which we cannot control. The methods used by Regan (2008) would be most applicable, but we had doubts about the exclusion restriction with our data, as no instrument at hand would fulfil the requirements at this point. Endogeneity issues remain to be solved in future studies.

A lack of IPR data in our estimations is also a limitation, but we assume this should not affect our results because substitutable products cannot have monopoly-status in the markets if generic competition occurs in the Finnish system. An external reference pricing system, based on other countries basket price-references are used for innovative and in-patent drugs when other domestic references for acceptable wholesale prices do not exist. In an EU commission study (2013), ten countries were reported as applying external reference pricing, as supportive criterion for in-patent (or innovative) drugs in Belgium, Finland, Italy, Poland, Spain and Germany and more binding for Cyprus, Estonia, France, Greece, Hungary, Norway, and Portugal. External reference pricing via a basket system may sustain high brand-name prices in smaller markets if competition does not occur in bigger countries within the same basket. A firm's profit can be positive even though they might be losing smaller markets by keeping brand name prices high. Decreasing price in one country may force a lower product price in every country within the same basket.

Generic substitution and reference price systems are known to decrease prices (Galizzi et al. 2011) but studies on the long-run effect are rare. To our knowledge, Granlund (2010) is the only study that provides a reference to our setup of a generic substitution study with a long-run perspective. Granlund's (2010) empirical results suggest that prices went down by 10% on average in long-run effects of Sweden GS after the policy implementation. Substitutable brand name prices decreased by 16% whereas substitutable generics decreased by 9%. Long-run estimates yielded a greater price effect in Granlund's (2010) study.

Our results differ from Granlund's (2010) results. We observed also falling prices, but the substitutable generics prices decrease heavily compared to substitutable brand name drugs. Different results may arise from differences in data classification strategy compared to our study, in terms of therapeutic bias, as mentioned in the identification section. Another important driver can be the underlying policy environment in Sweden. From 1993 to September 2002 Sweden had applied a reference price system, which was changed to a generic substitution system in October 2002.

Mixed results can also occur with applied reference price systems: Brekke et al. (2009; 2011) have studied the effect of reference price system in Norway, and Pavcnik (2002) in Germany respectively. Both studies show that reference pricing decreases the prices of pharmaceuticals but brand-names prices decrease more than generics. Kaiser et al. (2014) studied a change from an external to an internal reference price in Denmark. Their results differ from the results of Brekke (2009; 2011) and Pavcnik (2002), as the change in the Danish systems yields greater price reductions for generics and a minor negative effect for brand names.

The market environments are comparable among Nordic countries as they all apply a very similar form of regulation. We use the studies of Brekke et al. (2009; 2011), Granlund (2010) and Kaiser et al. (2014) as the main references due to their similar methodology to ours. We acknowledge the institutional differences between generic substitution and reference prices, but from a broader perspective, comparisons can be made. Both types of policies should yield cost containment, which they do, but the outcomes seem to be different. This underlines the importance of policy design being applied, which obviously plays an important role in market outcomes. The existing literature provides evidence that in applying a reference pricing system, it is a common outcome for brand name drugs to decrease in price more than generics (Merino – Castello 2003; Miraldo 2009). This can be due to the fact that the reference price system creates different incentives for price competition compared to generic substitution, as the behaviour of firms in a reference price system can be endogenous (Miraldo 2009; Merino-Castello 2003). Reference pricing is commonly linked with previous-period-observed prices and a profit maximizing firm may not have an incentive to decrease drug prices as low as they would without the RP system.

Incentives as defined by Miraldo (2009) may explain the observed outcomes of applied reference price systems in Brekke et al. (2009; 2011) if generics do not have an incentive for decreased prices as much as brand names. Kaiser et al.'s (2014) study provides contradictory results, but our interpretation is that a switch from an external to internal RP system creates similar incentives to enhance price competition as seen with GS, even though the policies are design-specific. Moreover, Kaiser et al.'s (2014) data cover only statin-class pharmaceuticals, which may limit the comparability or their results to ours.

6. Concluding remarks

The purpose of our study was to utilize the applied Finnish GS policy as a natural experiment and estimate the outcomes of policy on branded and generic drug prices. We contribute to existing studies with long-term effect estimates and refined the setup with several post-policy estimates for price effects.

In this study we derived a theoretical model for an applied generic substitution policy as a mean of increasing consumer's information about alternative products. Predictions show that we can end up with a standard regime of competition between brand-name and generics or under certain conditions, we can end up with a segmented regime where competition does not occur between generics and brand name pharmaceuticals.

In the empirical section we estimated the applied generic substitution policy price effects with the Finnish data set. The empirical results eventually support the standard markets regime, where competition occurs in long-term estimates in multi-period modelling. The two-period modelling results lend support to a segmented market result in terms of zero effect, but the results are not robust when compared to the refined model estimates.

Appendix A1

Proof of Lemma 1 Let us first consider pairs of prices (p,p_b) in the set

$$S_1 = \left\{ (p, p_b) \in R_+^2 \left| \left(\frac{s_b}{s_g} \right) p < p_b < \frac{\Delta}{\lambda} + p, 0 \le p \le \frac{s_g}{\lambda} \right. \right\}. \tag{3.1}$$

For such prices both the branded firm and generic firms compete for price-sensitive patients. Hence the profit function of generic firm i = 1,2,…,n is defined as follows:

$$\pi_i^1 = (p^1 - c)q_i - F = \frac{s_g}{s_b}\left[p_b - \left(\frac{\Delta}{\Phi\lambda} \right) Q \right] q_i - F, \tag{3.2}$$

where $Q = \sum_{i=1}^{n} q_i$. Let $q^1 = (q^1_1, q^1_2, \ldots, q^1_n)$ denote interior Nash equilibrium outputs. Equilibrium outputs must satisfy the system of first-order conditions:

$$\frac{\partial \pi_i^1}{\partial q_i} = \frac{s_g}{s_b}\left[p_b - \frac{\Delta}{\Phi\lambda}\left(Q + q_i \right) \right] = 0 \tag{3.3}$$

for i = 1,2,…,n. Second-order conditions are satisfied in an interior equilibrium, because the profit function (3.2) is a strictly concave function in output q_i for all i = 1,2,…,n. Summing up the first-order conditions (3.3) gives an equality

$$\frac{s_g}{s_b}\left[n p_b - (n+1)\left(\frac{\Delta}{\Phi\lambda} \right) Q \right] = 0, \tag{3.4}$$

which can be solved with respect to the aggregate supply of generic pharmaceuticals

$$Q^1 = Q^1(p_b) = \frac{\Phi n}{n+1}\frac{\lambda p_b}{\Delta}. \tag{3.5}$$

The equilibrium price of generic pharmaceuticals is

$$p_i^1 = p^1(p_b) = \frac{s_g}{s_b}\frac{p_b}{n+1} \tag{3.6}$$

for all i = 1,2,….,n. The Nash equilibrium is symmetric and generic firm i produces the n^{th} fraction of the aggregate equilibrium output

$$q_i^1(p_b) = \frac{Q(p_b)}{n} = \frac{\Phi}{n+1}\frac{\lambda p_b}{\Delta}. \tag{3.7}$$

Equilibrium profit of generic firm i is

$$\tilde{\pi}_i^1 \equiv \pi_i^1(p_b) = \Phi\frac{s_g}{s_b}\frac{\lambda}{\Delta}\left(\frac{p_b}{n+1}\right)^2 - F. \tag{3.8}$$

The equilibrium is an interior solution if $p^1(p_b) > p_b - (\Delta/\lambda)$ or

$$p_b < \frac{\Delta}{\lambda}\left(\frac{s_b(n+1)}{s_b n + \Delta}\right) \equiv L. \tag{3.9}$$

Let us then consider price pairs (p,p_b) in the set

$$S_2 = \left\{(p, p_b) \in R_+^2 \,\middle|\, \frac{\Delta}{\lambda} + p < p_b \le \frac{s_b}{\lambda}, 0 \le p \le \frac{s_g}{\lambda}\right\}. \tag{3.10}$$

The profit function of generic firm i = 1,2,…,n is now defined as

$$\pi_i^2 = p^2 q_i - F = \frac{s_g}{\lambda}\left(1 - \frac{Q}{\Phi}\right)q_i - F, \tag{3.11}$$

where $Q = \sum_{i=1}^{n} q_i$. Let $q^2 = (q^2_1, q^2_2, \ldots, q^2_n)$ denote interior Nash equilibrium outputs. The system of first-order conditions is

$$\frac{\partial \pi_i^2}{\partial q_i} = \frac{s_g}{\lambda}\left(1 - \frac{Q}{\Phi} - \frac{q_i}{\Phi}\right) = 0 \tag{3.12}$$

for i = 1,2,…,n. Using the same techniques as above, we can solve for equilibrium aggregate output of generic firms

$$Q^2(p_b) = \frac{\Phi n}{n+1}, \tag{3.13}$$

equilibrium prices of generic firms

$$p_i^2 = p^2(p_b) = \frac{s_g}{\lambda}\frac{1}{n+1} \tag{3.14}$$

and firm outputs

$$q_i^2 = q^2(p_b) = \frac{\Phi}{n+1} \tag{3.15}$$

for all i = 1,2,…,n. The equilibrium profit of firm i is

$$\pi_i^2 = \Phi\frac{s_g}{\lambda}\left(\frac{1}{n+1}\right)^2 - F. \tag{3.16}$$

The above equilibrium is an interior solution if $p^2(p_b) < p_b - (\Delta/\lambda)$ or when

$$p_b > \frac{1}{\lambda}\left(\Delta + \frac{s_g}{n+1}\right) \equiv \mathrm{U}. \tag{3.17}$$

Now it is straightforward to demonstrate by direct computation that L < U. This suggests that the characterization of the best response of the generic pharmaceuticals is not yet complete and we need to find the price best response of generic firms for prices p_b in the interval [L,U].

Our final task is to show that if the price of the branded pharmaceutical satisfies the conditions $L \leq p_b \leq U$, no generic firm has an incentive to deviate from the symmetric equilibrium in which each generic firm charges a price $p^3(p_b) = p_b - (\Delta/\lambda)$, the generic industry output is

$$Q^3(p_b) = \frac{\Phi\lambda}{s_g}\left(\frac{s_b}{\lambda} - p_b\right) \tag{3.18}$$

and each firm produces output

$$q_i = q \equiv \frac{\Phi\lambda}{ns_g}\left(\frac{s_b}{\lambda} - p_b\right) \tag{3.19}$$

To check that no generic firm wants to deviate from output q, assume that all other firms than firm i produce q. Then the profit of firm i is

$$\pi_i^{\,3} = \begin{cases} \dfrac{s_g}{s_b}\left(p_b - \dfrac{\Delta}{\Phi\lambda}\left(q_i + (n-1)q\right)\right)q_i - F, \ \textit{if } q_i < q \\ \dfrac{s_g}{\lambda}\left(1 - \left(\dfrac{q_i + (n-1)q}{\Phi}\right)\right)q_i - F, \qquad \textit{if } q_i \geq q. \end{cases} \tag{3.20}$$

Both parts of the firm i′s profit are strictly concave functions in q_i with unique maximum points. The first part of the firm i's profit has its unconstrained maximum point at

$$q_i^{\,1}(q) = \frac{1}{2}\left[\left(\frac{\Phi\lambda}{\Delta}\right)p_b - (n-1)q\right], \tag{3.21}$$

and the second part obtains its unconstrained maximum at the point

$$q_i^{\,2}(q) = \frac{1}{2}\left[\Phi - (n-1)q\right]. \tag{3.22}$$

It is now possible to show that that $q_i^{\,2}(q) \leq q$, if and only if $p_b \leq U$, and that $q_i^{\,1}(q) \geq q$, if and only if, $p_b \geq L$. These two observations and the strict concavity of the firm i's profit function implies that the profit i is maximized at $q_i = q$, and firm i has no incentive to deviate from the output q. Since the same argument holds for all generic firms in the market, firm outputs $q^3 = (q,q,\ldots,q)$, the aggregate output $Q^3(p_b)$ and price $p^3(p_b)$ form an equilibrium. ||

Proof of Lemma 2 Given $p(p_b)$, the reduced-form profit of the branded firm is defined as follows

$$\tilde{\pi}_b = \begin{cases} \left[(1-\Phi)\left(1 - \dfrac{\lambda p_b}{s_b}\right) + \Phi\left(1 - \dfrac{\lambda p_b}{\Delta}\,\dfrac{s_b n + \Delta}{s_b(n+1)}\right)\right]p_b, \ \textit{if } p_b < L \\ \left(1-\Phi\right)\left(1 - \dfrac{\lambda p_b}{s_b}\right)p_b, \qquad\qquad \textit{if } p_b \geq L \end{cases} \tag{3.23}$$

Let the functions[4] $v_1(p_b)$ and $v_2(p_b)$ denote the first and the second parts of the profit function (3.23), respectively. Both functions are continuous in their relevant domains. Moreover, because the branded firm

4 To simplify the notation, we do not introduce arguments n and Φ into the functions $v_1(.)$ and $v_2(.)$.

loses all price-sensitive consumers, when $p_b \geq L$, it holds true that $v_1(L) = v_2(L)$, and the profit function (1.15) is a continuous function for all non-negative prices.

Let us denote unconstrained maximum points of the first and the second parts the functions $v_1(.)$ and $v_2(.)$ by p_b^1 and p_b^2. It is straightforward to demonstrate that both functions are strictly concave functions in p_b, which implies that the unconstrained maximum points are unique and can be found by analysing the respective first-order conditions.

The first-order condition of the first part of the profit function is given as follows:

$$\frac{\partial v_1(p_b)}{\partial p_b} = (1-\Phi)\left(1-\frac{\lambda p_b}{s_b}\right)+\Phi\left(1-\frac{\lambda p_b}{\Delta}\frac{s_b n+\Delta}{s_b(n+1)}\right)-$$

$$\lambda p_b\left[\frac{1-\Phi}{s_b}+\frac{\Phi}{\Delta}\left(\frac{s_b n+\Delta}{s_b(n+1)}\right)\right]=0, \tag{3.24}$$

which can be solved with respect to the unconstrained maximum point

$$p_b^{\,1} = \frac{s_b}{2\lambda}F(n,\Phi), \tag{3.25}$$

where

$$F(n,\Phi) \equiv \frac{\Delta(n+1)}{\Delta(n+1)+\Phi\, s_g n}. \tag{3.26}$$

The second first-order condition

$$\frac{\partial v_2(p_b)}{\partial p_b} = (1-\Phi)\frac{1}{s_b}(s_b - 2\lambda p_b) = 0 \tag{3.27}$$

can be solved with respect to the unconstraint maximum point

$$p_b^{\,2} = \frac{s_b}{2\lambda}, \tag{3.28}$$

It is immediately clear that $p_b^1 \leq p_b^2$ because $F(n,\Phi) \leq 1$ for any pair (n,Φ). It is also worthwhile to observe that $F(0,\Phi) = 1$ for any feasible policy and $F(n,0) = 1$ for any generic market structure. In both of these cases, the branded firm essentially operates as a monopoly firm in the market. Moreover, it is straightforward to show that $dF/dn < 0$ and $dF/d\Phi < 0$.

In order to characterize the profit-maximizing price of the branded firm, it is necessary to compare the two maxima $v_1(p_b^1)$ and $v_2(p_b^2)$ with each other. The maxima of the function $v_2(.)$ is given as follows

$$v_2(p_b^2) = \frac{s_b}{4\lambda}\left(1-\Phi\right). \tag{3.29}$$

On the other hand, the maxima of the first part of the profit function (3.23) is given as

$$v_1(p_b^1) = \frac{s_b}{4\lambda}\left[\left(1-\Phi\right)\left(2-F(n,\Phi)\right)F(n,\Phi) + \Phi\left(2-F(n,\Phi)\left(\frac{s_b n+\Delta}{\Delta(n+1)}\right)\right)F(n,\Phi)\right] =$$

$$\frac{s_b}{4\lambda}\left[\frac{(1+n)\Delta}{(1+n)\Delta+ns_g\Phi}\right] = \frac{s_b}{4\lambda}F(n,\Phi). \tag{3.30}$$

The branded firm is better off charging the monopoly price from the loyal consumers than competing with generic firms if and only if

$$1-\Phi \geq F(n,\Phi) \equiv \frac{(1+n)\Delta}{(1+n)\Delta+ns_g\Phi}, \tag{3.31}$$

or, alternatively, when

$$n(2s_g - s_b - s_g\Phi) \geq \Delta. \tag{3.32}$$

If $s_b \geq 2s_g$, the condition (3.32) cannot be met, because the left-hand side of the equality (3.32) becomes negative while the right-hand side is strictly positive. This implies that the profit maximizing price is (3.30) if the condition $s_b \geq 2s_g$ holds true.

If $s_b < 2s_g$, then it follows from the condition (3.32) that the market outcome is segmented, if the policy parameter satisfies the condition

$$\Phi \leq \frac{2s_g - s_b - \Delta n^{-1}}{s_g} \equiv SEG(n). \tag{3.33}$$

Since any feasible generic substitution policy must satisfy the condition $0 \leq \Phi$, the other condition for the segmented market outcome is that the number of generic firms must be higher than $(2s_g - s_b)/\Delta$. ||

Appendix A2. Data conversions

Excluded ATC-groups: A02BC04, C07AB12, C09CA06, C10AA04, N03AG04, N03AX16, N05AX12, N06AB10, N06AX21
Excluded packet numbers: 182733, 582486, 182741, 86587, 529735, 523969, 442418, 179622, 537860, 46987, 558536
Exclude packets with two or more quarter's gaps (do not allow exit from markets and re-entering).
Exclude packets if time in the markets is strictly less than 12 quarters, with a gap of 2 quarters.
Exclude packets if substitution takes place and removes, seven observations.
Exclude packets if substitution does not take place before the 44th quarter.
Exclude packets if price/DDD is zero or negative.
Exclude product level (aggregated) observation if appearance in the markets is less than a year.
Exclude liquid form drugs, undefined packet size or dosage strength as follows:

packet size		
1 ml	250 ml	10 x 5 ml
2 ml	300 ml	28 x 10 g
3 ml	400 ml	6 + 3 + 1
5 ml	50 x 1	100 dosage
50 g	500 ml	14 + 14 +14
10 ml	56 x 1	50 x 500 mg
15 ml	800 ml	7 + 21 + 21
20 ml	100 x 1	25 mg + 2 ml
28 ml	11 + 14	30 + 14 + 14
40 mg	20 x 10	4 x 50 x 5 g
60 ml	21 + 14	50 mg + 2 ml
70 ml	49 + 49	40 mg + 10 ml
0.5 ml	5 x 1 ml	37.5 mg + 2.0 ml
100 ml	5 x 2 ml	14 + 30 + 10 + 14
120 ml	5 x 3 ml	10 x 2 ml
150 ml	5 x 5 ml	10 x 1 ml
200 ml	50 x 5 g	

Strength	
10 mg / 12.5 mg	20 mg / 6 mg
10 mg / 25 mg	300 microg*
100 mg / 25 mg	4 mg / 1.25 mg
100 microg*	40 mg / 12.5 mg
1000 mg/dosage	42 mg Li
16 mg / 12.5 mg	5 mg / 12.5 mg
160 mg / 12.5 mg	50 mg / 12.5 mg
160 mg / 25 mg	500 mg/dose
180 mg / 2 mg	600 mg / 12.5 mg
2.5 mg / 12.5 mg	80 mg / 12.5 mg
20 mg / 12.5 mg	1 ED / 2 ED

*Micrograms are converted to Mg into a new strength variable and included dataset

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