Online Appendix

Market size and strategic interaction in pharmaceutical price regulation

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Published in
The Scandinavian Journal of Economics

A.1 Theoretical analysis

A.1.1 Relationship between reservation prices and relative market size

Consider the system of equations defining the reservation prices r^A and r^B as a function of the relative market sizes in countries A and B:

$$\begin{aligned} \Pi^A(r^A(n^A), r^B(n^A), n^A) &= n^A(r^A - m)\hat{q}^A - C^A = 0, \\ \Pi^B(r^A(n^A), r^B(n^A), n^A) &= (1 - n^A)(r^B - m)\hat{q}^B - C^B = 0. \end{aligned} \tag{A.1}$$

Applying the methods described in Section 3, we can characterise the relationship between reservation price and relative market size by replacing the variables that are relevant to the application to pharmaceutical price regulation into Eq. (6):

$$\frac{\partial r^A}{\partial n^A} = \frac{-\Pi^A_{n^A}\Pi^B_{r^B} + \Pi^B_{n^A}\Pi^A_{r^B}}{\Pi^A_{r^A}\Pi^B_{r^B} - \Pi^A_{r^B}\Pi^B_{r^A}}. \tag{A.2}$$

The denominator of Eq. (A.2) is strictly positive when the product of the direct effects of an increase in reservation price on own-country profits exceeds the indirect effects. The numerator

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of the RHS of Eq. (6) may be written as:

$$-\Pi^A_{n^A}\cdot\Pi^B_{r^B}+\Pi^B_{n^A}\cdot\Pi^A_{r^B}=-\left(r^A-m\right)\left[\hat{q}^A+n^A\frac{\partial\hat{q}^A}{\partial n^A}\right]\cdot(1-n^A)\left[\hat{q}^B+(r^B-m)\frac{\partial\hat{q}^B}{\partial r^B}\right]+$$
$$+\left(r^B-m\right)\left[-\hat{q}^B+(1-n^A)\frac{\partial\hat{q}^B}{\partial n^A}\right]\cdot n^A(r^A-m)\frac{\partial\hat{q}^A}{\partial r^B}. \tag{A.3}$$

The analysis in Section 4.4.2 shows that $\partial\hat{q}^B/\partial r^B$ is strictly positive providing the reservation price is smaller than the price optimally set by the regulator. Therefore, $\Pi^B_{r^B}>0$. We also know that $\Pi^A_{r^B}$ is positive, because $\partial\hat{q}^A/\partial r^B>0$, due to the fact that an increase in r^B increases $\hat{q}^A$ via its impact on I^*. Hence, other things being equal, own country profits increasing in own country relative market size ($\Pi^A_{n^A}>0$, and therefore $\Pi^B_{n^A}<0$) is a sufficient condition for $\partial r^A/\partial n^A<0$. Eq. (A.3) also shows that, with n^A sufficiently small, the term in the first row is unambiguously negative, with the other term going to zero as n^A goes to zero. Hence $\partial r^A/\partial n^A<0$.

A.1.2 Implications of the assumptions on $\hat{q}^A(\cdot)$

In Section 4.4.2 we introduce the assumption that $\hat{q}^A(\cdot)$ is strictly concave in p^A. Here we investigate the conditions under which it holds and show that these are satisfied for some very standard functional forms for the production function δ.

Given the definition of $\hat{q}^A$ in Eq. (17),

$$\frac{\partial^2\hat{q}^A}{\partial p^A\partial p^A}=\frac{\kappa^A}{b^A}\left[\frac{\partial^2\delta}{\partial I^2}\left(\frac{\partial I^*}{\partial p^A}\right)^2+\frac{\partial\delta}{\partial I}\frac{\partial^2 I^*}{\partial p^A\partial p^A}\right]. \tag{A.4}$$

The application of the implicit function theorem to Eq. (15) enables us to obtain an expression for $\partial I^*/\partial p^A$, from which the expression for $\partial^2 I^*/\partial p^A\partial p^A$ follows. After substituting these partial and cross-partial derivatives into Eq. (A.4) and performing standard algebraic simplifications, Eq. (A.4) may be written as,

$$\frac{\partial^2\hat{q}^A}{\partial p^A\partial p^A}=\frac{b^A(b^B)^4(n^A)^2(\kappa^A)^3}{\xi^4(\partial^2\delta/\partial I^2)}\left[3-b^Ab^B\frac{\partial^3\delta/\partial I^3}{\xi(\partial^2\delta/\partial I^2)^2}\right], \tag{A.5}$$

where $\xi=n^A(p^A-m)\kappa^Ab^B+(1-n^A)(p^B-m)\kappa^Bb^A>0$. Since the term that multiplies the expression in brackets is negative, the condition that ensures that $\hat{q}^A$ is strictly concave in p^A is:

$$\frac{\partial^3\delta/\partial I^3}{(\partial^2\delta/\partial I^2)^2}<\frac{3\xi}{b^Ab^B}. \tag{A.6}$$

Although the interpretation of the condition is not immediately intuitive, it is easy to see that it holds, for example, for a logarithmic functional form. To see this, start by calculating the ratio between the third derivative and the squared second derivative for the specific functional form of interest. Substitute the value of I^* that solves Eq. (15) into this expression, observing that the first order condition for I^* can be written as $\frac{\partial \delta}{\partial I} = \frac{b^A b^B}{\xi}$. For the case of the logarithmic function, $\frac{\partial^3 \delta / \partial I^3}{(\partial^2 \delta / \partial I^2)^2} = \frac{2\xi}{b^A b^B}$, so that the condition is always satisfied.

A.1.3 Proof of Proposition 2

When $\alpha^A = 1$, $\partial \hat{q}^A / \partial p^A = 0$ at the value of p^A that maximises W^A. Hence, the sign of $\partial p^{A*} / \partial n^A$ is the same as the sign of $\partial^2 \hat{q}^A / \partial p^A \partial n^A$ (refer to Eq. (20)). This proves the proposition.

In what follows, we explore under which conditions $\partial^2 \hat{q}^A / \partial p^A \partial n^A > 0$ is satisfied. From Eq. (17) it may be shown that:

$$\frac{\partial^2 \hat{q}^A}{\partial p^A \partial n^A} = \frac{\kappa^A}{b^A} \left[\frac{\partial^2 \delta}{\partial I^2} \frac{\partial I^*}{\partial p^A} \frac{\partial I^*}{\partial n^A} + \frac{\partial \delta}{\partial I} \frac{\partial^2 I^*}{\partial n^A \partial p^A} \right]. \tag{A.7}$$

Using a similar approach to that of Appendix A.1.2, $\partial I^* / \partial n^A$ and $\partial^2 I^* / \partial n^A \partial p^A$ can be derived from Eq. (15). It is possible to show that, under reasonable assumptions regarding the functional form of $\delta(I)$, the sign of (A.7) is positive, which proves Proposition 2. For example, using a logarithmic function, the equation can be rewritten as follows:

$$\frac{\partial^2 \hat{q}^A}{\partial p^A \partial n^A} = \left(\frac{\kappa^A b^A (b^B)^2}{\xi^3 (\partial^2 \delta / \partial I^2)} \right) \left(\frac{\partial \xi / \partial p^A}{n^A} \right) \left(\epsilon_{\xi, n^A} - 1 \right), \tag{A.8}$$

where ϵ_{ξ, n^A} is the elasticity of ξ with respect to n^A and ξ was defined in Appendix A.1.2. Noting that the first term in parentheses on the RHS of this expression is strictly negative (because $\partial^2 \delta / \partial I^2 < 0$) and the second term is strictly positive, the proposition is satisfied if the last term is negative. At an interior solution for p^B, it is easy to confirm that the final term in Eq. (A.8) is strictly negative. At a corner solution ($p^B = r^B$), this term is negative if $\epsilon_{r^B, n^A} < \frac{1}{1 - n^A}$, which is the case when n^A is sufficiently large, which is also the condition under which $p^B = r^B$.

A.1.4 Proof of Proposition 3

Using similar reasoning to that used in the proof of Proposition 2, when $\alpha^A = 1$, the sign of $\partial p^{A*}/\partial\kappa^A$ is the same as the sign of

$$\frac{\partial^2 \hat{q}^A}{\partial p^A \partial \kappa^A} = \frac{1}{b^A}\left[\frac{\partial\delta}{\partial I}\frac{\partial I^*}{\partial p^A} + \kappa^A\left(\frac{\partial^2\delta}{\partial I^2}\frac{\partial I^*}{\partial\kappa^A}\frac{\partial I^*}{\partial p^A} + \frac{\partial\delta}{\partial I}\frac{\partial^2 I^*}{\partial\kappa^A\partial p^A}\right)\right]. \tag{A.9}$$

Expressions for the partial and cross-partial derivatives in this equation can be obtained from Eq. (15) and substituted into Eq. (A.9), which leads to the following expression:

$$\frac{\partial^2 \hat{q}^A}{\partial p^A \partial \kappa^A} = \frac{(b^A)^2(b^B)^3\kappa^A n^A}{\xi^4(\partial^2\delta/\partial I^2)}\left[-2(1-n^A)(p^B-m)\kappa^B - \frac{(b^B)^2 n^A\kappa^A(p^A-m)\partial^3\delta/\partial I^3}{\xi(\partial^2\delta/\partial I^2)^2}\right]. \tag{A.10}$$

Since the term multiplying the expression in brackets is negative, the assumption $\partial^3\delta/\partial I^3 \geq 0$ is sufficient for $p^{A*}(p^B)$ to be strictly increasing in κ^A.

A.1.5 Comparative statics and proof of Proposition 4

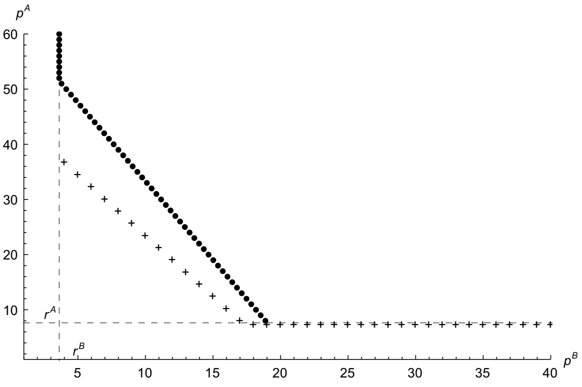
By replacing the variables of interest for the model of pharmaceutical price regulation into Eq. (8), we obtain:

$$\frac{\partial p^{A*}}{\partial n^A} = \left[-W^A_{p^A n^A}W^B_{p^B p^B} + W^B_{p^B n^A}W^A_{p^A p^B}\right][|\mathbf{H}|]^{-1}, \tag{A.11}$$

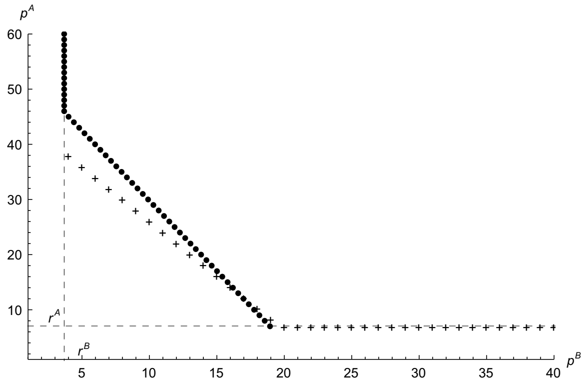
where $\mathbf{H}$ is the determinant of the Hessian of a dynamical system in (p^A, p^B). Given our focus on stationary equilibria, we may refer to the ideas of Dixit (1986) to conclude that $|\mathbf{H}| > 0$. Hence $\text{sign}[\partial p^{A*}/\partial n^A] = \text{sign}\left[-W^A_{p^A n^A}W^B_{p^B p^B} + W^B_{p^B n^A}W^A_{p^A p^B}\right]$. When the weight of CS in the welfare function is sufficiently large, prices are strategic substitutes ($W^A_{p^A p^B} < 0$, see Section 4.5), $W^A_{p^A n^A} > 0$ (Proposition 2) and $W^B_{p^B n^A} < 0$ (Corollary 1). Since at an optimal value of p^B, $W^B_{p^B p^B} < 0$, the conditions mentioned in Proposition 4 are sufficient, because, under those conditions, the numerator is the sum of two strictly positive terms.

A.1.6 Simulation

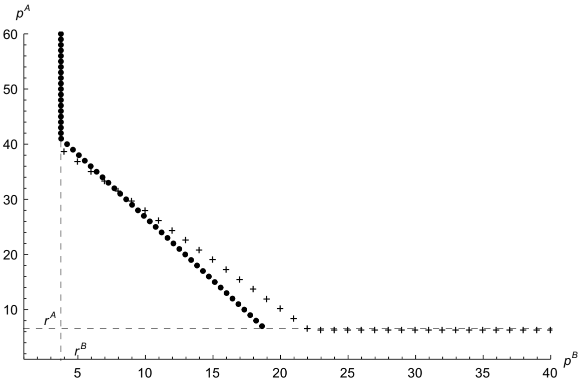
The aim of this section is to use a simulation to illustrate the mechanism described by Corollary 1, which plays an important role for the interpretation of our empirical results. In particular, we show a situation where, as a result of the increase in n^A, country A moves from a corner to an interior solution. We use a logarithmic function for δ, i.e. $\delta(I) = \ln[I]$. The other parameter



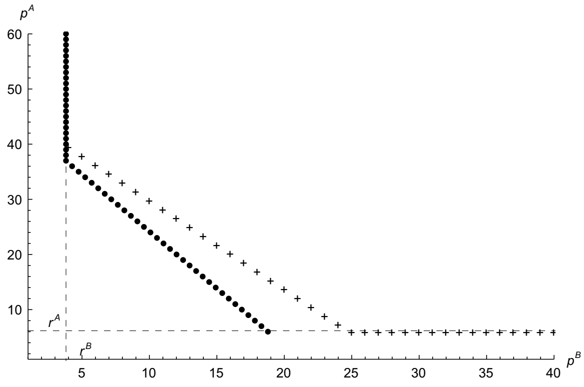
(a) $n^A = 0.22$. Equilibrium prices: $p^A = r^A = 7.63$, $p^B = 19.18$.



(b) $n^A = 0.24$. Equilibrium prices: $p^A = 14.33$, $p^B = 16$.



(c) $n^A = 0.26$. Equilibrium prices: $p^A = 33.58$, $p^B = 7$.



(d) $n^A = 0.28$. Equilibrium prices: $p^A = 41.61$, $p^B = r^B = 3.81$.

Figure A.1: Nash equilibria for different values of n^A. '+': $p^{A*}(p^B)$; '•': $p^{B*}(p^A)$. Dashed line represent reservation prices.

values are: $\kappa^A = 25$, $\kappa^B = 20$, $b^A = b^B = 1$ $N = 100$, $m = 1$, $\alpha^A = 0.6$, $\alpha^B = 0.8$, $\lambda = 0.85$, $C^A = 25,000$, $C^B = 35,000$.

We start by assuming $n^A = 0.22$ for the first simulation and then increase the value by 0.02 in three subsequent rounds. Figure A.1 illustrates the results. The relevant value of n^A is reported in the figure's legend, together with the Nash equilibrium approximate values of prices.

Since no closed form solution exists for $p^{c*}(p^{-c})$, in Figure A.1 best responses are approximated by a discrete number of numerical solutions. In Figure A.1a, country A's best response lies below country B's, leading to a Nash equilibrium where $p^A = r^A$ and country B responds optimally. Consistent with the results of Section 4.5, an initial increase in n^A shifts country A's and B's best responses respectively upwards and downwards. Increasing n^A from 0.22 to 0.24 (Figure A.1b) implies a move from an equilibrium where country A is at a corner solution to one where it is at an interior solution (Corollary 1). A further increase (Figure A.1c) increases the Nash equilibrium price for country A further (Proposition 3), still keeping both prices above their respective reservation levels. Finally, with a further increase in n^A, country B's price is at a corner, with country A responding optimally (Figure A.1d).

A.2 Empirical analysis

A.2.1 Diseases and products included in the empirical analysis

Table A.1 lists the 28 different neoplasm causes available in the GBD 2015 data set for which prevalence data are available.

Of the 108 antineoplastic drugs available for our analysis, our final sample includes 83. These are listed in Table A.2, together with the number of adopting countries for each product. Six of the excluded drugs do not treat cancer, 3 treat some types of cancer for which prevalence data are not available from our source, two are hybrid drugs which lack the degree of innovation that is central in our analysis (a hybrid drug contains the same active substance as an authorised drug, but differs on some other characteristics such as strength, indication or pharmaceutical form). In addition, ten were not on patent in any country in our sample during the period of analysis; in such cases, price may be affected by generic competition, which is not accounted for in our theoretical model. Two are included in the original EMA list, but not in our price data set because of their very recent market launch. Finally, 2 drugs are lost because they were introduced only in the US.

Bladder cancer	Leukemia	Ovarian cancer
Brain and nervous system cancer	Lip and oral cavity cancer	Pancreatic cancer
Breast cancer	Liver cancer	Prostate cancer
Cervical cancer	Malignant skin melanoma	Stomach cancer
Colon and rectum cancer	Mesothelioma	Testicular cancer
Esophageal cancer	Multiple myeloma	Thyroid cancer
Gallbladder and biliary tract cancer	Nasopharynx cancer	Tracheal, bronchus and lung cancer
Hodgkin lymphoma	Non-Hodgkin lymphoma	Uterine cancer
Kidney cancer	Non-melanoma skin cancer	
Larynx cancer	Other pharynx cancer	

Table A.1: List of neoplasm causes, as identified by the Global Burden of Diseases database 2015.

Product	Number of countries	Product	Number of countries	Product	Number of Countries
Abraxane	12	Iclusig	13	Sutent	22
Adcetris	17	Imbruvica	16	Tafinlar	20
Afinitor	20	Imlygic	7	Tagrisso	10
Arzerra	16	Inlyta	21	Tarceva	21
Atriance	16	Iressa	19	Targretin	2
Avastin	19	Jakavi	21	Tasigna	21
Blincyto	12	Javlor	13	Temodal	2
Bosulif	17	Jevtana	19	Teysuno	14
Cabometyx	5	Kadcyla	20	Torisel	18
Caprelsa	18	Keytruda	18	Trisenox	18
Cometriq	8	Kisplyx	5	Tyverb	20
Cotellic	10	Kyprolis	15	Unituxin	1
Cyramza	15	Lenvima	14	Vargatef	13
Dacogen	15	Litak	1	Vectibix	21
Darzalex	10	Lonsurf	10	Velcade	16
Depocyte	2	Lynparza	15	Venclyxto	7
Empliciti	8	Mabthera	21	Vidaza	16
Erbitux	20	Mekinist	11	Votrient	22
Erivedge	13	Nexavar	22	Xalkori	19
Evoltra	1	Ninlaro	5	Xaluprine	11
Farydak	9	Onivyde	1	Xeloda	2
Foscan	1	Opdivo	18	Yervoy	21
Gazyvaro	18	Perjeta	18	Yondelis	17
Giotrif	21	Pixuvri	9	Zaltrap	16
Glivec	1	Portrazza	6	Zelboraf	19
Halaven	16	Spectrila	2	Zydelig	15
Herceptin	21	Sprycel	22	Zykadia	14
Ibrance	9	Stivarga	18		

Table A.2: Products included in the sample, together with the number of adopting countries.

A.2.2 Proxy variable for the manufacturer's incentive to introduce a confidential discount

The first step for the construction of a variable measuring the size of the market potentially affected by a price set in country c at time t – our proxy for the strength of the incentive to introduce confidential discounts from the manufacturer's perspective – is the identification of the reference basket for each country over the period of interest. To this end, we collected information from several sources to record, on an annual basis, the countries whose ERP rules

	2007	2008	2009	2010	2011	2012
Austria	B F G H I IT NO SK E CH	B F G H I IT NO SK E CH	B D F G H I IT NO SK E CH	B D F G H I IT NO SK E CH	B D F DE G H I IT NO SK E CH	B D F DE G H I IT NO P SK E CH
Belgium	A F G H I IT N NO P SK E	A F G H I IT N NO P SK E	A D F G H I IT N NO P SK E	A D F G H I IT N NO P SK E	A D F DE G H I IT N NO P SK E	A D F DE G H I IT N NO P SK E
Czech R	A B F G H IT P SK	A B F G H IT P SK	A B F G H IT P SK	A B F G H IT P SK	A B F DE G H IT P SK	A B F DE G H IT P SK
Denmark	A B F G I IT NO P SK CH	A B F G I IT NO P SK CH	A B F G I IT NO P SK CH	A B F I IT NO P SK CH	A B F DE H I IT NO P SK CH	A B F DE H I IT NO P SK CH
Finland	A B G I IT NO SK E	A B G I IT NO SK E	A B D G I IT NO SK E	A B D G I IT NO SK E	A B D DE G H I IT NO SK E	A B D DE G H I IT NO P SK E
France	A B C F G H I IT J K N P PR SK E CH T	A B C F G H I IT J K N P PR SK E CH T	A B C F G H I IT J K N P PR SK E CH T	A B C F G H I IT J K N P PR SK E CH T	A B C F DE G H I IT J K N P PR SK E CH T	A B C F DE G H I IT J K N P SK E CH T
Germany	A B F FR G H I IT J K N NO P SK E CH	A B F FR G H I IT J K N NO P SK E CH	A B D F FR G H I IT J K N NO P SK E CH	A B D F FR G H I IT J K N NO P SK E CH	A B D F FR G H I IT J K N NO P SK E CH	A B D F FR G H I IT J K N NO P SK E CH
Greece	A B C F H IT P PR SK E T	A B C F H IT P PR SK E T	A B C F H IT P PR SK E T	A B C F H IT P PR SK E T	A B C F DE H IT P PR SK E T	A B C F DE H IT P SK E T
Hungary	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK
Ireland	A B F G H IT NO P SK E	A B F G H IT NO P SK E	A B D F G H IT NO P SK E	A B D F G H IT NO P SK E	A B D F DE G H IT NO P SK E	A B D F DE G H IT NO P SK E
Italy	A B C F FR G H K P PR SK E T	A B C F FR G H K P PR SK E T	A B C F FR G H K P PR SK E T	A B C F FR G H K P PR SK E T	A B C F FR DE G H K P PR SK E T	A B C F FR DE G H K P PR SK E T
Japan	K	K	K	K	K	K
Korea						
Luxemburg	A B F G IT P SK E	A B F G IT P SK E	A B F G IT P SK E	A B F G IT P SK E	A B F G H IT P SK E	A B F G H IT P SK E
Netherlands	A B F G I IT NO P SK E CH	A B F G I IT NO P SK E CH	A B D F G I IT NO P SK E CH	A B D F G I IT NO P SK E CH	A B D F DE G H I IT NO P SK E CH	A B D F DE G H I IT NO P SK E CH
Norway	F	F	D F	D F	D F H	D F H P
Poland	A B F G H IT SK	A B F G H IT SK	A B F G H IT SK	A B F G H IT SK	A B F G H IT SK	A B F G H IT SK
Portugal	A B C F G H IT P SK E T	A B C F G H IT P SK E T	A B C F G H IT P SK E T	A B C F G H IT P SK E T	A B C F DE G H IT P SK E T	A B C F DE G H IT P SK E T
Slovak R	A B F G H IT	A B F G H IT	A B F G H IT	A B F G H IT E	A B F DE G H IT E	A B F DE G H IT P E
Spain	A B C F FR G H I IT K P PR SK T	A B C F FR G H I IT K P PR SK T	A B C F FR G H I IT K P PR SK T	A B C F FR G H I IT K P PR SK T	A B C F FR DE G H I IT K P PR SK T	A B C F FR DE G H I IT K P PR SK T
Sweden	A B F G IT NO P SK	A B F G IT NO P SK	A B D F G IT NO P SK	A B D F IT NO P SK	A B D F DE H IT NO P SK	A B D F DE H IT NO P SK
Switzerland	G K P	G K P	G K P	G K P	G H K P	G H K P
Turkey						
UK	A B F FR G I IT J K N NO P SK CH	A B F FR G I IT J K N NO P SK CH	A B D F FR G I IT J K N NO P SK CH	A B D F FR G I IT J K N NO P SK CH	A B D F FR DE G H I IT J K N NO P SK CH	A B D F FR DE G H I IT J K N NO P SK CH
US	J	J	J	J	J	J

For each country (in rows) and each year (in columns), the table reports the list of countries whose ERP rules refer to that country. Abbreviations are as follows, A: Austria; B: Belgium, C: Czech R; D: Denmark; F: Finland; FR: France; DE: Germany; G: Greece; H: Hungary; I: Ireland; IT: Italy; J: Japan; K: Korea; L: Luxembourg; N: Netherlands; NO: Norway; P: Poland; PR: Portugal; SK: Slovak R; E: Spain; S: Sweden; CH: Switzerland; T: Turkey.

Table A.3: List of referring countries: 2007-2012.

	2013	2014	2015	2016	2017
Austria	B D F DE G H I IT NO P SK E CH	B D F DE G H I IT NO P SK E CH	B D F DE G H I IT NO P SK E CH	B D F DE G H I IT NO P SK E CH	B D F DE G H I IT NO P SK E CH
Belgium	A C D F DE G H I IT N NO P SK E	A C D F DE G H I IT N NO P SK E	A C D F DE G H I IT N NO P SK E CH	A C D F DE G H I IT N NO P SK E CH	A C D F DE G H I IT N NO P SK E CH
Czech R	A B F DE G H IT P SK	A B F DE G H IT P SK	A B F DE G H IT P SK	A B F DE G H IT P SK	A B F DE G H IT P SK
Denmark	A B C F DE H I IT NO P SK CH	A B C F DE H I IT NO P SK CH	A B C F DE G H I IT NO P SK CH	A B C F DE G H I IT NO P SK CH	A B C F DE G H I IT NO P SK CH
Finland	A B C D DE G H I IT NO P SK E	A B C D DE G H I IT NO P SK E	A B C D DE G H I IT NO P SK E CH	A B C D DE G H I IT NO P SK E CH	A B C D DE G H I IT NO P SK E CH
France	A B C F DE G H I IT J K	A B C F DE G H I IT J K	A B C F DE G H I IT J K	A B C F DE G H I IT J K	A B C F DE G H I IT J K
	N P SK E CH T	N P PR SK E CH T	N P PR SK E CH T	N P PR SK E CH T	N P PR SK E CH T
Germany	A B D F FR G H I IT J	A B D F FR G H I IT J	A B D F FR G H I IT J	A B D F FR G H I IT J	A B D F FR G H I IT J
	K N NO P SK E CH	K N NO P SK E CH	K N NO P SK E CH	K N NO P SK E CH	K N NO P SK E CH
Greece	A B C F DE H IT P SK E T	A B C F DE H IT P SK E T	A B C F DE H IT P SK E T	A B C F DE H IT P SK E T	A B C F DE H IT P SK E T
Hungary	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK	A B C F G IT P SK
Ireland	A B C D F DE G H IT NO P SK E	A B C D F DE G H IT NO P SK E	A B C D F DE G H IT NO P SK E	A B C D F DE G H IT NO P SK E	A B C D F DE G H IT NO P SK E
Italy	A B C F FR DE G	A B C F FR DE G	A B C F FR DE G	A B C F FR DE G	A B C F FR DE G
	H K P PR SK E T	H K P SK E T	H K P SK E T	H K P SK E T	H K P SK E T
Japan	K	K	K	K	K
Korea					
Luxemburg	A B F G H IT P SK E	A B F G H IT P SK E	A B F G H IT P SK E	A B F G H IT P SK E	A B F G H IT P SK E
Netherlands	A B C D F DE G H I IT NO P SK E CH	A B C D F DE G H I IT NO P SK E CH	A B C D F DE G H I IT NO P SK E CH	A B C D F DE G H I IT NO P SK E CH	A B C D F DE G H I IT NO P SK E CH
Norway	D F H P	D F H P	D F H IT P	D F H IT P	D F H IT P
Poland	A B C F G H IT SK	A B C F G H IT SK	A B C F G H IT SK	A B C F G H IT SK	A B C F G H IT SK
Portugal	A B C F DE G H IT P SK E T	A B C F DE G H IT P SK E T	A B C F DE G H IT P SK E T	A B C F DE G H IT P SK E T	A B C F DE G H IT P SK E T
Slovak R	A B C F DE G H IT P PR E	A B C F DE G H IT P PR E	A B C F DE G H IT P E	A B C F DE G H IT P PR E	A B C F DE G H IT P PR E
Spain	A B C F FR DE G H	A B C F FR DE G H	A B C F FR DE G H	A B C F FR DE G H	A B C F FR DE G H
	I IT K P PR SK T	I IT K P PR SK T	I IT K P PR SK T	I IT K P PR SK T	I IT K P PR SK T
Sweden	A B C D F DE H IT NO P SK	A B C D F DE H IT NO P SK	A B C D F DE G H IT NO P SK	A B C D F DE G H IT NO P SK	A B C D F DE G H IT NO P SK CH
Switzerland	H K P	H K P	K	H K	F H IT K P
Turkey					
UK	A B C D F FR DE G H I IT	A B C D F FR DE G H I IT	A B C D F FR DE G H I IT	A B C D F FR DE G H I IT	A B C D F FR DE G H I IT
	J K N NO P SK CH	J K N NO P SK CH	J K N NO P SK CH	J K N NO P SK CH	J K N NO P SK CH
US	J	J	J	J	J

For each country (in rows) and each year (in columns), the table reports the list of countries whose ERP rules refer to that country. Abbreviations are as follows, A: Austria; B: Belgium, C: Czech R; D: Denmark; F: Finland; FR: France; DE: Germany; G: Greece; H: Hungary; I: Ireland; IT: Italy; J: Japan; K: Korea; L: Luxembourg; N: Netherlands; NO: Norway; P: Poland; PR: Portugal; SK: Slovak R; E: Spain; S: Sweden; CH: Switzerland; T: Turkey.

Table A.4: List of referring countries: 2008-2013.

refer to each country in our data set.[4]

A summary of this information is presented in Tables A.3 and A.4. The variable of interest is defined as the sum of the prevalence of the diseases for which product i has an indication, in all the countries belonging to our initial sample of 25 countries whose basket at time t includes country c. For the country-year combinations for which no specific information was available, it was assumed that no change occurred if the basket was the same in the last year before the gap and the first year after the gap. If no change in the reference set occurs over the years for which information is available, the first and the last basket reported were carried backwards and forward, respectively. Full details can be provided by the authors upon request. Products are matched with diseases following the same criteria outlined in Section 5.1.

A.2.3 Further robustness checks

In this section, we describe the additional robustness checks that we carried out to explore the stability of the U-shaped result suggested by our baseline empirical analysis. Results are reported in Table A.5 and Figures A.2 to A.4.

Figures A.2a and A.2b show predictions for the models whose results are reported in Columns (3) and (4) of Table 3 in the main text. As additional robustness checks, we consider a semi-parametric approach to choosing the optimal degree of the polynomial for the relative market size, selected according to a cross-validation criterion.[5] According to this criterion, a polynomial of degree three should be used, so column (1) of Table A.5 presents the results for this model. A comparison between the predictions for this model (Figure A.2c) and Figure 5 shows that allowing for greater flexibility in the functional form leads to a flatter curve above a relative market size of approximately 0.11. Below that level, the shape is similar and the minimum points for the two figures are also similar (a minimum of 0.951 for a relative market size of 5.7% in Figure 5 and a minimum of 0.940 for a relative market size of 4.5% in Figure A.2c). Overall, the results confirm that price is first decreasing and then increasing in the relative size

[4] Kanavos and Vandoros (2011), Maini and Pammolli (2023), Europe Economics (2013), Leopold et al. (2008, 2012), Toumi et al. (2014), EFPIA (2014), European Commission (2015), Panteli et al. (2016), Schneider and Vogler (2019), Gill et al. (2019), Arts et al. (2007), Zimmermann and Vogler (2012), DeSwaef and Antonissen (2007a,b), Antonissen and DeSwaef (2009), Zalesakova (2009), Thomsen et al. (2007), Er (2009), Özer et al. (2011), Mäntyranta et al. (2007), Van Ganse et al. (2007, 2008), Dauben et al. (2008), Vardica and Kontozamanis (2007), Kovács et al. (2007), Elliott (2007), Martini and Folino Gallo (2007), Jang et al. (2019), Frostelid et al. (2007), Festöy et al. (2008), Festøy and Ognøy (2015), Janiszewski and Bondaryk (2007), Mazag and Segec (2007), Martínez Vallejo et al. (2010), Redman and Köping Höggärd (2007), Pontén et al. (2017), Tatar (2007, 2013, 2017), Kullman (2010).

[5] The cross-validation criterion splits the sample into a training and a validating set, with the training set being used to estimate the parameters and the preferred model selected according to its predictive performance in the validating set Stone (1974); Geisser (1975); Zhang and Yang (2015).

	Dependent variable: ln(price per mg)			
	Trimmed sample		Untrimmed sample	
	OLS	GLM	OLS	OLS
	(1)	(2)	(3)	(4)
Relative market size	-7.031***	-3.910***	-1.410***	-1.790***
	(2.509)	(1.073)	(0.464)	(0.494)
Relative market size (squared)	106.110**	35.209***	9.422**	11.962***
	(52.046)	(12.204)	(3.965)	(4.241)
Relative market size (cubed)	-422.165			
	(303.271)			
Natural Logarithm of GDP per capita	0.140***	0.116***	0.165***	0.157***
	(0.018)	(0.018)	(0.019)	(0.019)
Natural Logarithm of pharmaceutical exports	0.024***	0.022***	0.019***	0.022***
	(0.002)	(0.002)	(0.002)	(0.002)
Number of years since launch date	-0.024***	-0.022***		-0.024***
	(0.004)	(0.004)		(0.004)
Number of observations	19766	19766	20155	20155
U-shape test ($p - value$)			0.019	0.007
Extreme point			0.075	0.075

All models include product-level fixed effects.
Standard errors (in parentheses) are clustered at the product level.
Product FE included.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

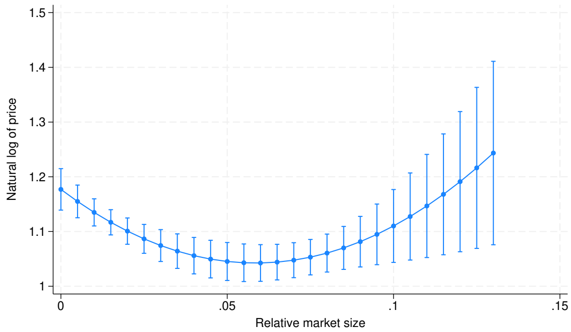
Table A.5: Further robustness checks: OLS with relative market size cubed (column (1)), GLM (column (2)) and results for the untrimmed sample (columns (3) and (4)).

of the market. The results in column (1) of Table A.5 also show that this specification has little impact on the estimated coefficients for the control variables. Furthermore, Column (2) of the table shows that estimating a Generalized Linear Model (GLM) with a polynomial of degree 2, a Log as the link function and a Gamma distribution for errors (as suggested by the modified Park test of Manning and Mullahy (2001)) yields results that are qualitatively the same as in our main specification. Figure A.2d shows the predictions for this model.

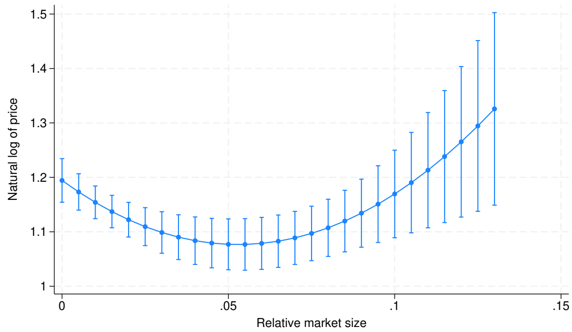
Columns (3) and (4) of Table A.5 report the results for the same analysis reported in columns (1) and (2) of Table 3, using the untrimmed sample instead of the trimmed one. Figure A.3 replicates what was shown for the baseline sample in Figure 5 of the main text. The results are qualitatively very similar.

Our main results (Columns (1) and (2) of Table 3 in the main text) are also robust to including a dummy variable denoting whether the drugs were on, or off, patent. This is unsurprising, given that only 3% of the observations in our sample are off patent.

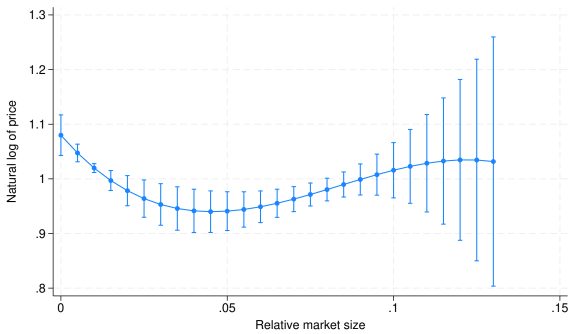
Finally, we also estimate the model using two non-parametric methods and the original, i.e. trimmed, sample. Figure A.4a shows the results for a cubic spline with 3 knots, located at the default percentiles of relative market size suggested by Harrell et al. (2001) (10^{th}, 50^{th} and 90^{th}). The other non-parametric method is Kernel-Based Regularized Least Squares (KRLS) Hainmueller and Hazlett (2014), a machine learning method that has at least two interesting properties for our setting. First, unlike other methods used so far, it does not require any assumptions concerning specific functional forms. Second, it allows for interactions among virtually all of the parameters, which may be interesting, given the complexity of the relationships shown by the theory. This procedure provides an estimate of the derivative of price with respect to the variable of interest, relative market size, for each data point. Figure A.4b shows that the derivatives tend to be lower, and negative on average, for low values of the relative market size and positive for high values, which is again consistent with the idea of a U-shaped relationship between market size and price.



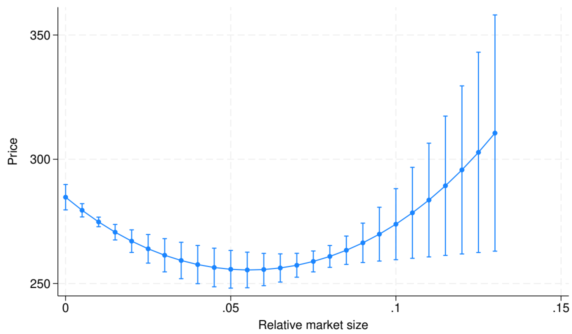
(a) NLLS (column (3) of Table 3). Predictive margins with 95% CI.



(b) NLLS with additional explanatory variable of the one-sided error (column (4) of Table 3). Predictive margins with 95% CI.



(c) OLS with non-parametric determination of the polynomial degree (column (1) of Table A.5). Predictive margins with 95% CI.



(d) GLM (column (2) of Table A.5). Predictive margins with 95% CI.

Figure A.2: The relationship between the predicted value of the Natural Logarithm of price and relative market size, with 95% CI (robustness checks, Table A.5).

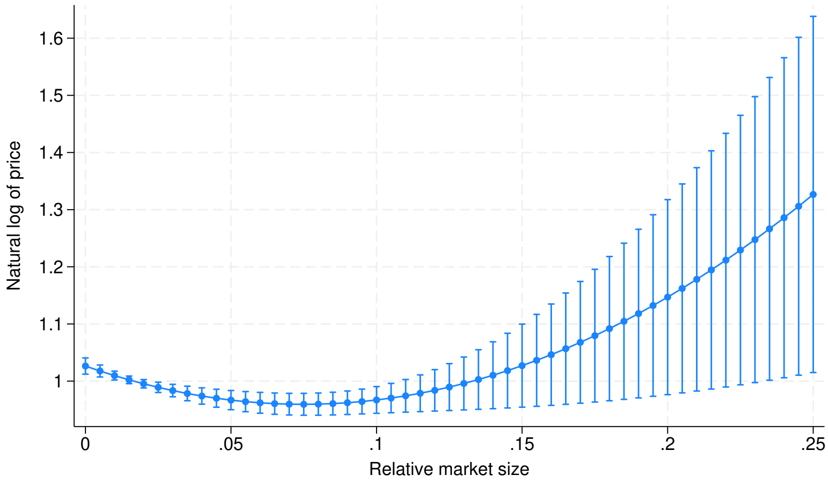
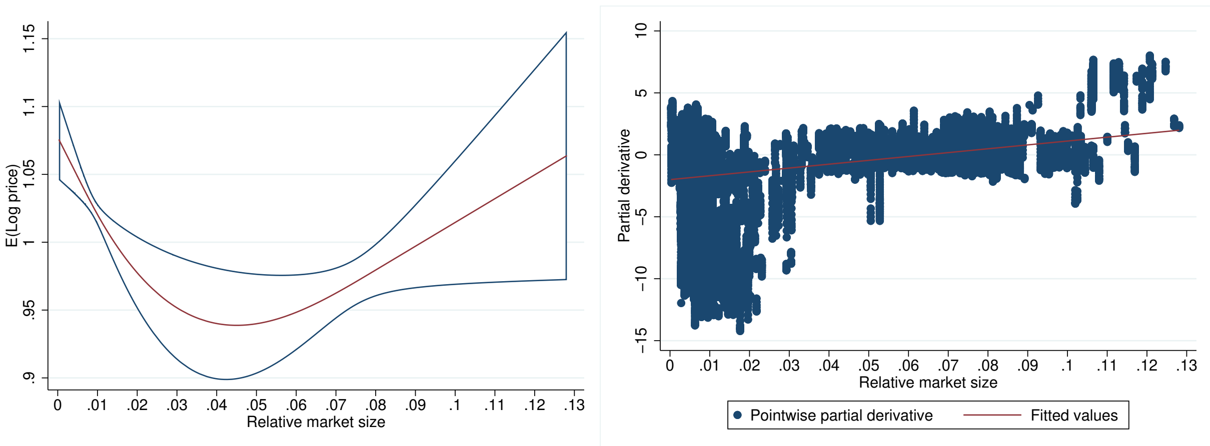


Figure A.3: Untrimmed sample: relationship between the predicted value of the Natural Logarithm of price and relative market size (column (4) of Table A.5), with 95% CI.



(a) Cubic spline. Predictive margins with 95% CI.

(b) KRLS

Figure A.4: Non-parametric estimations.

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