Bargaining and International Reference Pricing in the Pharmaceutical Industry

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December 2021 §

Abstract

The United States spends twice as much per person on pharmaceuticals as European countries, in large part because prices are much higher in the US. This fact has led policymakers to consider legislation for price controls. This paper assesses the effects of a US international reference pricing policy that would cap prices in US markets by those offered in reference countries. We estimate a structural model of demand and supply for pharmaceuticals in the US and reference countries like Canada where prices are set through a negotiation process between pharmaceutical companies and the government. We then simulate the counterfactual international reference pricing equilibrium, allowing firms to internalize the cross-country externalities introduced by these policies. We find that such a policy would result in much smaller price decreases in the US than price increases in reference countries. The magnitude of these effects depends on the number, size and market structure of references countries.

Keywords: Pharmaceuticals, International Reference Pricing, Most Favored Nation Clause, Bargaining, Empirical Industrial Organization.

JEL Codes: L11, L13, L22, I18, I11, C51, C57

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§We thank many participants on seminars at Toulouse, Harvard, Yale, Princeton, Boston University, University of Vienna, UNC Chapel Hill, University of Arizona, NYU Stern, CREST Paris, UC Irvine, University of Massachusetts (Amherst), Stanford, CBO, Georgetown, Universidad Catholica de Chile, University of Lyon, Hong Kong University of Science and Technology, University of Pennsylvania, $(IO)^2$ seminar and in the following conferences: Bates-White Life Sciences Symposium 2019, World Congress of the Econometric Society 2020, IIOC 2021, ASSA 2021, LACEA Health Economics Network. We are also grateful for a NIHCM grant.

1 Introduction

The pharmaceutical industry represents a significant part of the global economy: global pharmaceutical sales amounted to $1.1 trillion in 2016, forty percent of which came from the US.[1] Policymakers around the world face the challenge of balancing the long-term benefits of pharmaceutical R&D incentives against the more immediate benefits of regulating or negotiating lower drug prices (Lakdawalla et al., 2009; Lakdawalla, 2018). Innovating new drugs is expensive.

DiMasi et al. (1991, 2003, 2016) document a steady evolution in the cost of innovation—figures that rise from $230 million (1987) to $500 million (2000) to $1.4 billion (2013).[2] Given the substantial cost of R&D, the profits that a pharmaceutical firm expects to make off of a drug play a large role in the firm's decision to invest in developing it. Pull incentives are however insured by the patent protection system such that valuable innovation are developed even if the expected cost of R&D grows. Indeed, new drugs are protected from competition by patents in order to ensure adequate profitability, and breakthrough drug prices often greatly exceed their marginal costs of production, ensuring high profitability. For example, Gilead Sciences priced its breakthrough hepatitis C drug, Sovaldi, at $1,000 per pill—a price that almost certainly exceeds its marginal cost.[3] These high prices are usually considered as the necessary reward for innovation, even in countries where drug prices are regulated.

Moreover, the social planner's problem is further complicated by the fact that the benefits to pharmaceutical R&D may spill over to other countries. While there exists a theoretical literature on the international spill overs of intellectual property protection on innovation —see, for example, Helpman (1993) and Grossman and Lai (2004)—there is more limited empirical work on cross-country effects. For example, Chaudhuri et al. (2006) examines quinolone sales data to determine the effect of TRIPS global patent protection on welfare. They find substantial welfare losses to the Indian economy, resulting from the enforcement of foreign pharmaceutical intellectual property rights in India. Moreover, it has been shown that pharmaceutical industry profits as a whole affect R&D. Acemoglu and Linn (2004), Blume-Kohout and Sood (2013) and Dubois et al. (2015) demonstrate a positive elasticity of innovation in relation to market size. Acemoglu et al. (2006) examines whether the introduction of Medicare affected pharmaceutical innovation and shows a positive effect, as well. Filson (2012) defines a dynamic-stochastic equilibrium model of innovation and fits it to industry facts in order to assess counterfactuals in which either the US adopts price controls or other countries drop theirs. Dynamic models of R&D have also been

[1] QuintilesIMS Global Pharma Outlook 2016 (https://www.iqvia.com/-/media/iqvia/pdfs/institute-reports/global-outlook-for-medicines-through-2021.pdf).

[2] To obtain these numbers, we adjusted the figures reported in the papers for inflation.

[3] "Sales of Sovaldi, New Gilead Hepatitis C Drug, Soar to $10.3 Billion." Feb. 3, 2015. *New York Times.*

employed to study other industries, such as high- and low-tech manufacturing (Peters et al., 2017).

However, as the US spends twice as much as European countries per inhabitant in pharmaceuticals—mostly because of substantially higher prices—price controls in the US have been increasingly called for in policy circles (Salter, 2015; OECD, 2017), and recently, by the US administration with the H.R.3 Lower Drug Costs Now Act of 2019 and the H.R. 5376 Build Better Back Act of 2021.[4] For example, Salter (2015) discusses international reference pricing for the US as a way to reduce pharmaceutical spending, using experience in other developed countries as evidence of price reduction effects. Weiss et al. (2016) say that the US government may reduce the differential pricing that exists with respect to other markets by using an international reference pricing policy (though price controls may only be achieved following re-referencing as the US is typically a first-launched market). Such a policy was implemented on a small scale in the 1990s when the US Federal Government included a Most Favored Customer clause on pharmaceutical product prices supplied to Medicaid. Scott-Morton (1997) shows that, while firms had to provide Medicaid at their lowest price, the rule resulted in higher prices to some non-Medicaid consumers of pharmaceuticals. Finally, Adams (2021) models drug price negotiations that could be occurring under the H.R. 3 legislation (reintroduced under HR 5376), where the constraint that the price should be less than a maximum fair price defined as 120 percent of an average international market price. In Europe, most price control policies base price setting on external reference pricing—pricing of the same drugs in other countries. In the case of the US, and unlike Canada or most European countries, drug pricing is not currently negotiated by a centralized regulatory authority that can adopt more or less aggressive negotiating standards. The advantage of an international reference pricing policy is then that it only requires an ex post control that US prices should not be higher than prices for the same drugs in referenced countries. However, none of these approaches accounts for the equilibrium effects of international reference pricing on the pricing equilibrium both in the implementing and reference countries.

In this paper, we develop a model that allows us to simulate a counterfactual international reference pricing policy in which price controls are introduced in the US, in reference to other countries' prices. Such a policy may imply changes in equilibrium prices, both in the US and the reference countries. Using data from the US and Canada, our paper develops and estimates a structural model of supply and demand that allows us to assess how prices are set both in Canada and the US. In Canada, this amounts to estimating the marginal costs of products and the bargaining weights of firms that negotiate prices with regulators. In the US, it entails a

[4]See https://www.congress.gov/bill/116th-congress/house-bill/3/ and https://www.congress.gov/bill/117th-congress/house-bill/5376

Bertrand-Nash equilibrium in prices across competing firms. This gives us a setting in which we can evaluate counterfactual prices, demand, and welfare given different international pricing regimes. In particular, we simulate a policy in which the US constrains prices offered in its markets by the prices offered in Canada. In equilibrium, firms internalize the restrictions imposed by US reference pricing when negotiating with Canada. They also internalize the effects of Canadian price setting when negotiating with the US.[5] We then extend the one country reference pricing model to multiple countries where the reference price used by the US is an average price of several countries. Our approach is novel in that we study the equilibrium price setting that results due to reference pricing—both on prices in the country adopting a price control and in the reference countries. As such, we determine welfare and profit effects in the global pharmaceutical market equilibrium.

We use detailed data on drug quantities and prices from IMS Health to estimate a random coefficient logit model of demand with estimated drug class-specific market sizes. We then model the price setting in a country with regulated prices (such as Canada) as the result of negotiation between pharmaceutical manufacturers and a regulator under a Nash bargaining equilibrium (Horn and Wolinsky, 1988; Crawford and Yurukoglu, 2012; Grennan, 2013; Gowrisankaran et al., 2015; Dubois and Sæthre, 2020). With these supply side assumptions, we are able to separately identify costs and bargaining parameters. Since Nash bargaining involves maximizing the weighted log-sum of both parties' transaction utilities, we can interpret the bargaining parameters as the degree to which the country policymaker chooses to trade off between firm profits and immediate consumer welfare.

Given our estimates of preferences, marginal costs, and bargaining parameters, we then assess counterfactual policy simulations in which pharmaceutical prices in the United States are subject to international reference pricing. Under the assumption that cost and demand parameters would not change, we simulate the counterfactual prices that result. In our counterfactual equilibrium, firms internalize the constraint that US prices must be lower than prices in Canada or than an average of several similar countries, while simultaneous price negotiations in reference countries internalize the impact of the their result on price setting in the US.

Our results show that such a policy results in a slight decrease in US prices and a substantial increase in reference countries with an effect that becomes larger when more countries are included in the index. The magnitude of these effects depends on the particular structure of the policy. The effect appears to be asymmetric because of the size of differences in pharmaceutical markets across countries, the bargaining parameter value in the reference country (Canada),

[5] In counterfactuals in which the US imposes reference pricing, we assume that price setting is set via negotiations with regulators as is the case in other countries that use reference pricing schemes.

firms' marginal costs and the shape of demand in each country. Overall, we find modest consumer welfare gains in the US, but substantial consumer welfare losses in reference countries. Moreover, we find that pharmaceutical profits may increase in net only when the index price is from a single country but that they are reduced in net when the index average more countries' prices, suggesting that the policy would reduce overall pharmaceutical profit in addition to consumer welfare in reference counties to the short term benefit of US consumers. The overall welfare effect of such policy even for US consumers only would thus depend on how pharmaceutical profits would benefit consumers in the long run through innovation. Our analysis sheds new light on the price effects of reference pricing and shows the costs and benefits of a most favored nation policy in the US.

The effects demonstrated by our analysis are in addition to the negative impacts that previous work has shown reference pricing to have on entry in referenced countries (Danzon and Chao (2000), Danzon et al. (2005), Maini and Pammoli (2017)). Our analysis holds entry/exit fixed and so it does not internalize such an effect.

Our paper is structured as follows. Section 2 presents the data used for Canada and the US. Section 3 presents the demand model that we use for each market and country, as well as its identification method. Section 4 introduces the supply side models, both for regulated and unregulated pharmaceutical markets, that we estimate in order to identify structural supply side parameters. It then presents the supply side identification method and estimation results. Finally, section 5 develops a counterfactual model of international reference pricing. Section 6 concludes.

2 Data and Descriptive Statistics

We use data from IMS Health (now called IQVIA) on revenues and quantities of drugs sold to hospitals at the quarter level from 2002 to 2013. Our data spans the United States and Canada—the main markets in our study—as well as France, Germany, the UK, Italy, and Spain, which we use for auxiliary information on the market for each drug. Observations in our data are at the product-dosage level by country and quarter, and by hospital, retail or other channel of use. The data also includes product characteristics and the manufacturer name. We use the international drug name in the data to identify the same drug across countries. We then aggregate drugs across dosage forms and administering methods (e.g., tablets and injections) using "standard units"—the minimal dosage of a given drug—to compare different packages. Finally, we aggregate sales to the molecule-corporation-market level and aggregate all of the generics that are available

for each molecule. We compute quarterly drug prices as the ratio of total revenue and total quantity in standard units. We focus on prescription drugs and do not study the OTC market. We leave the question of the consequences of having country-specific definitions of OTC versus prescription drugs for future research.

We define markets for drugs based on the fourth level of the Anatomical Therapeutical and Chemical classification (ATC-4). In the ATC system, drugs are classified according to the organ or system on which they act and their therapeutic, pharmacological and chemical properties into five nested levels, ranging from the part of the body that the drug treats (ATC-1) to the particular molecule structure of the drug (ATC-5). For example, the classification of metformin (brand names: Glumetza, Fortamet, Glucophage, Riomet) is at the 1st Level (Anatomical Main Group): (A) Alimentary tract and metabolism; at the 2nd Level (Therapeutic Subgroup): (A10) Drugs used in diabetes; at the 3rd Level (Pharmacological Subgroup): (A10B) Blood glucose lowering drugs; at the 4th Level (Chemical Subgroup): (A10BA) Biguanides; and at the 5th Level (Chemical Substance): (A10BA02) Metformin. The ATC-4 class of a drug therefore captures the set of drugs that may reasonably be thought of as substitutes, as they have a similar chemical structure and are used for a similar treatment purpose.

We restrict our focus to the 31 ATC-4 classes for which we have at least one on-patent molecule both in Canada and in the US.[6] These 31 ATC-4 classes are drawn from a set of 25 ATC-3 classes that covers 93% of total hospital drug expenses in the US and 72% in Canada.

Table 2.1 shows descriptive statistics on the number of molecules by on-patent/off-patent branded and generic status within each ATC-4 class, in the US and in Canada. In addition, Table 2.1 displays the share of expenditures of US and Canadian hospital sector pharmaceutical spending that each ATC-4 class represents. There is variation across ATC-4 classes in the proportion of drugs with enforceable patents. ATC-4 classes in which most molecules' patents are expired typically have most drugs available in inexpensive generic form. In these cases, lowering prices in the US is of less interest.

There is also variation in the share of expenditures that different ATC-4 classes represent between Canada and the US. In Canada, anti-cancer drugs (L1 class) represent a relatively larger share of total expenses (around 35%) than the 20% that they represent in the US. By contrast, the share of US spending on injectable anesthetics (N1A2) is much larger (around 15%) than in Canada around (9%). The distribution of relative expenses across drug classes is thus different between the two countries, even though the US spends more in absolute value in every ATC-4 class and pays higher prices on almost all drugs, as shown in Table 7.1 in Appendix 7.1.

[6] That is, we exclude ATC-4 classes in which Canada does not have any on-patent molecules, while the US does. This typically happens because of the delayed entry of new molecules in Canada.

Although the composition of drugs sold within each class in each country is different, the ATC-4 level average price is much higher in the US in almost every class and quarter.

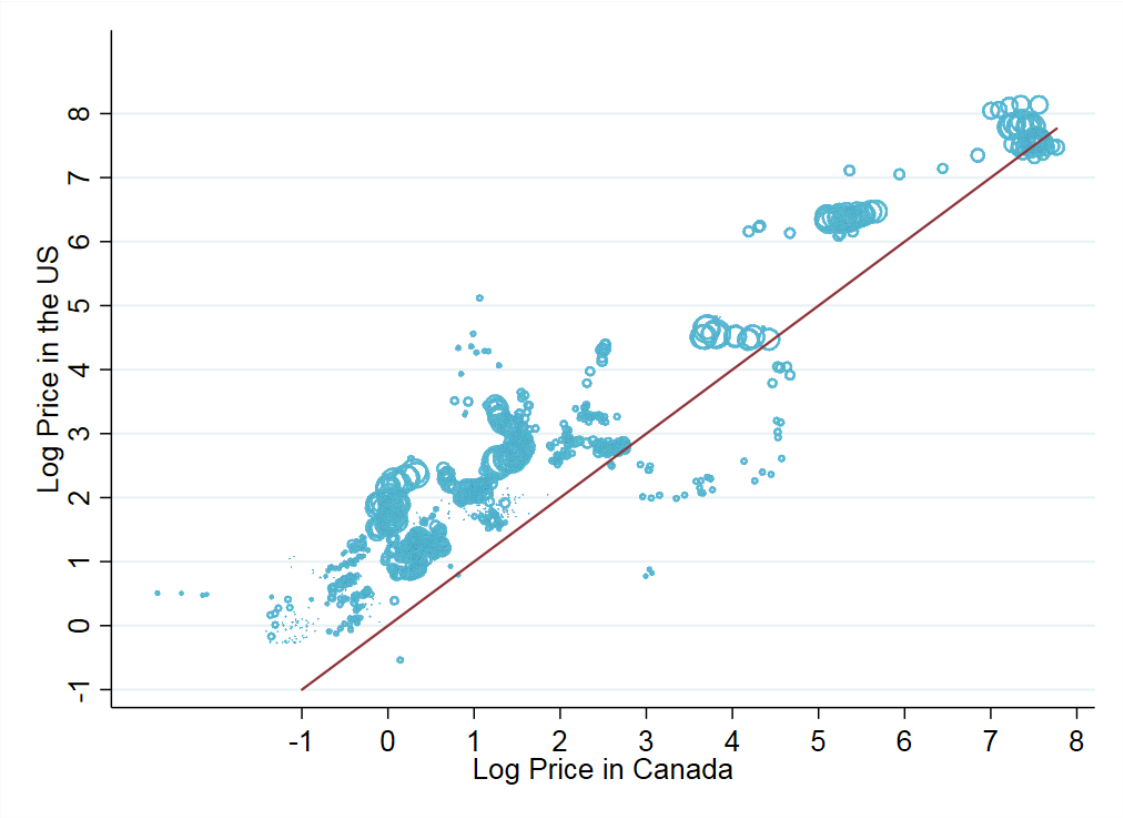
For drugs that are sold in both the US and Canada, it is interesting to verify that prices are indeed higher in the US than in Canada, as this is one of the motivation for policymakers to propose price control policies. Figure 2.1 shows a scatter plot of log prices in the US against log prices in Canada for the on-patent drugs present in both countries. As shown in the figure, most drugs are more expensive in the US than in Canada by a large amount that is increasing in absolute value with the price of the drug in Canada. However, the most expensive drugs are priced similarly across the two countries.

Table 2.1: *Number of molecules and expenditure shares by ATC-4*

		Canada				US			
		Number				Number			
ATC4	Label	On Patent	Branded Off Patent	Generics	Expenditure Share (%)	On Patent	Branded Off Patent	Generics	Expenditure Share (%)
A10H0	SULPHONYLUREA A-DIABS	1	1	4	0.05	1	1	5	0.10
C2A2	ANTIHYPER.PL MAINLY PERI	1	3	4	0.49	1	1	4	0.81
C7A0	B-BLOCKING AGENTS,PLAIN	3	3	8	0.20	2	5	10	0.64
C8A0	CALCIUM ANTAGONIST PLAIN	2	3	3	2.10	3	5	5	2.85
C9A0	ACE INHIBITORS PLAIN	7	2	4	2.33	4	3	7	0.99
L1B0	ANTIMETABOLITES	6	2	4	11.96	6	1	7	10.61
L1X9	ALL OTH. ANTINEOPLASTICS	3	1	1	11.32	8	0	3	5.71
L4X0	OTHER IMMUNOSUPPRESSANTS	4	1	2	23.51	6	2	4	13.56
M1A1	ANTIRHEUMATICS NON-S PLN	1	3	6	0.62	1	2	10	0.69
N1A2	INJECT GEN ANAESTHETICS	2	2	5	9.32	2	4	7	17.09
N1B1	ANAESTH LOCAL MEDIC INJ	2	2	3	2.17	2	1	5	2.71
N3A0	ANTI-EPILEPTICS	3	4	10	4.56	6	3	10	12.36
N5A1	ATYPICAL ANTIPSYCHOTICS	3	3	2	28.60	5	1	2	27.40
N5A9	CONVNTL ANTIPSYCHOTICS	6	3	8	0.17	3	2	8	0.24
N5B3	BARBITURATE PLAIN	1	0	1	0.02	1	0	2	0.06
N6A4	SSRI ANTIDEPRESSANTS	1	2	5	1.82	2	1	4	3.05
N6A9	ANTIDEPRESSANTS ALL OTH	3	3	12	0.76	3	2	12	1.15

Note: Average number of molecules (rounded to closest integer) and expenditure shares within country over 2002-2013, by ATC-4 classes (Details on classification in European Pharmaceutical Market Research Association (2018)).

Figure 2.1: *Comparisons of Prices of On-Patent Drugs present in both the US and Canada*



Note: Circle sizes are proportional to the sales value of this drug in the US.

Figure 7.1 in Appendix shows the same graph for generic drugs, that are also on average more expensive in the US than in Canada, especially for the cheapest drugs but for which the price ranking is less systematic than for on patent products. In the case of generic drugs, prices are affected by the within molecule competition, which seems to leave less room for price differences across countries.

3 Demand Model

Pharmaceutical bargaining depends, in large part, on consumers' substitution between competing drugs at different price levels. Regulators consider how each proposed price change will impact total consumption and expenses (and subsequently, welfare), while manufacturers consider how it will impact profits. In order to take this into account, we estimate a flexible model of aggregate consumer demand for drugs within each market. In order to best capture the substitution patterns that reflect a representative consumer, we model variation in preferences across hospitals with a standard random utility discrete choice framework in which consumers' utility is a function of prices and available drug characteristics.

Our decision to focus on the hospital sector stems from the structure of drug purchase decisions in hospitals. Hospitals typically internalize the prices of drugs that they purchase on behalf of patients, who compensate the hospitals at a per-diem basis. Drug consumption choices by hospitals can therefore be seen as reflecting knowledgeable, price-conscious prescribers who evaluate the merits of each available drug and choose the best option given the available price menu. While it is possible that there are differences in preferences between the hospital and retail sectors, we believe that an extrapolation based on hospital data alone yields the most interpretable predictions given available data. We do observe retail sales as well, but do not see data on the underlying behavior of insurers, healthcare providers or other intermediaries between patients and drug manufacturers. Our results can therefore either be interpreted as is, on the basis of hospital drug consumption, or extrapolated to the full economy on the basis of status quo ATC-4 consumption shares in each sector.

3.1 Demand Specification

We model the drug choice problem of a representative consumer as follows. A drug market is defined by a level 4 Anatomical Therapeutic Chemical (ATC-4) class, a country (e.g. Canada and the US), and a fiscal quarter. We denote fiscal quarters by t, countries by c and ATC-4 classes by m. Consumer preferences for each drug in a market are defined according to a random coefficient logit framework for differentiated products, following Berry et al. (1995) and Nevo (2001).

Within each country c, a representative consumer i chooses to purchase a drug j from the set of choices $j = 0, 1, .., J_{m(j)}$ available in j's market, $m(j)$, according to the indirect utility:[7]

$$U_{ijt} = u_{ijt} + \varepsilon_{ijt}$$

where

$$u_{ijt} = \alpha_i \ln p_{jt} + \beta_{im(j)} g_j + \gamma_i + \lambda_{m(j)} x_{jt} + \phi_j + \mu_{m(j)t} + \xi_{jt}.$$

We normalize the utility for the outside good (choosing not to purchase a drug), u_{i0t}, to zero. We denote p_{jt} for the price of drug j at t. Drug characteristics are captured by the drug's molecule identifier, patent status and generic status. In our utility specification, g_j is a binary variable indicating whether drug j is generic, x_{jt} is a binary variable indicating whether j's molecule

[7] All parameters and variables in the utility function, as well as the choice set within an ATC-4 class, are country-specific. We suppress the country index c for ease of exposition. Since each drug is only available in one ATC-4 class, we also suppress the m subscript in market denotations. That is, we consider the demand model country by country, and each unique market that a drug j is available in is denoted by t.

patent has expired by quarter t and ϕ_j is a molecule fixed effect. An unobserved shock at the drug-quarter level is denoted by ξ_{jt}.

Consumer preferences are captured by three types of random effects. Individual value for purchasing an inside good is captured by the random effect γ_i. Individual disutility from higher prices is captured by the random coefficient α_i on log prices.[8] Individual preferences for branded drugs are captured by the random coefficient β_{im} on the branded indicator variable. We assume that random coefficients are independently normally distributed with $\alpha_i \sim \mathcal{N}(\alpha, \sigma_\alpha)$, $\beta_{im} \sim \mathcal{N}(\beta_m, \sigma_\beta)$, $\gamma_i \sim \mathcal{N}(0, \sigma_\gamma)$, and denote the vectors of parameters $\theta = (\sigma_\alpha, \sigma_\beta, \sigma_\gamma)$. The mean utility for drug j in quarter j is thus given by

$$\delta_{jt} = \alpha \ln p_{jt} + \beta_{m(j)} g_j + \lambda_{m(j)} x_{jt} + \phi_j + \mu_{m(j)t} + \xi_{jt}.$$

Assuming that ε_{ijt} is i.i.d. extreme value distributed, the expected market share of product j in market mt where $m = m(j)$ is given by the aggregate probability that j will be chosen from the choice set in m:

$$s_{jt}\left(\delta_{jt}, \theta\right) = \int \frac{\exp\left(u_{ijt}\right)}{1 + \sum_{k=1}^{J_m} \exp\left(u_{ikt}\right)} dF(\nu_{im}; \theta) \tag{3.1}$$

where ν_{im} denotes the vector of random coefficients $\{(\alpha_i - \alpha), (\beta_{im} - \beta_m), \gamma_i\}$ and $F\left(.; \theta\right)$ denotes their joint c.d.f.

3.2 Demand Identification

We estimate our demand model according to the standard BLP method with instrumental variables for prices (Berry et al., 1995). We construct drug-quarter demand shocks $\xi_{jt}(\delta_{jt}, s_{jt}, \theta)$ by inverting a system that matches the theoretical market shares in equation (3.1) to observed market shares. We then form moment conditions by interacting the inverted demand shocks with a set of orthogonal instruments Z_{jt} so that

$$\mathbb{E}\left[Z_{jt} \xi_{jt}(\delta_{jt}, s_{jt}, \theta)\right] = 0.$$

The key challenge to estimation is the consistent estimation of the price coefficient distribution. We expect the process of price-setting to be affected by unobserved demand shocks ξ_{jt}, and so observed prices are likely to be correlated with $\xi_{jt}(\delta_{jt}, s_{jt}, \theta)$. Our identification thus depends

[8] We use a log price specification that fits better the data because we have very heterogeneous prices across different ATC-4 markets. While widely used in the literature (Björnerstedt and Verboven, 2016; Gowrisankaran and Rysman, 2012; Berry et al., 1995), it is known that this specification does not correspond to a closed form solution for its direct utility function.

on the use of instruments that affect prices but are orthogonal to ξ_{jt}. While the gold standard would be to collect direct cost-shifters for each drug, this is impractical for our exercise. In order to assess the effect of an international reference pricing policy on total hospital drug spending, we examine a large number of drugs across a large number of therapeutic classes. As such, it is unlikely that we would be able to find detailed cost-shifters that are relevant to all of the classes of drugs that we cover. Similarly, it would be unfeasible to collect specific cost-shifters for each drug or therapeutic class. One possibility would be to restrict our analysis to a few therapeutic classes, find class-specific cost shifters and identify the price coefficient only off of those therapeutic classes. However, this would limit the scope of our empirical assessment.

Instead, we leverage observed differences and changes in consumers' choice sets from quarter to quarter as our primary source of identification. In particular, we form instruments by collecting, for each drug j in each quarter t, the number of products in j's ATC-4 class, its (broader) containing ATC-3 class, the numbers of generics and off-patent branded drugs, both for j's molecule and in general within j's therapeutic class, and the number of countries (out of France, Germany, Canada, Spain, Italy, the UK and the US) in which j is offered in the hospital sector. These variables capture variation in the composition of drug j's competition that is largely driven by the entry of new drugs, the expiration of patents, and the exit of outdated drugs. Similarly to BLP instruments, identification is premised on the assumption that isolation in the product space predicts prices through the competitive channel. Similar logic may still hold even if prices are set through bargaining: products that are innovative and without clear substitutes may be able to extract more rent when bargaining. Moreover, while changes in the competitive landscape for drug j is thus likely to impact its price, the changes themselves are largely driven by the ascendance of time and technological progress. Drugs often face delays in entering markets outside the US due to additional regulatory hurdles. Furthermore, patent protection is determined long in advance and entry decisions can take years. Even generic entries often face delays from regulations, start-up costs, etc. and so they provide an additional source of choice set variation. As such, it is unlikely that any of these instruments will correlate with the idiosyncratic demand shocks ξ_{jt}.

In addition to checking the power of instrumental variables in a first stage regression, we consider using Hausman style instruments, as in Dubois and Lasio (2018). Identification using such instruments relies on the correlation between prices across markets due to common cost shocks rather than common demand shifters. To construct such instrumental variables, we perform country-level regressions of price on active ingredient dummies and quarter fixed effects, and we use the residuals as instruments for price. The instruments for the price of product j

in market $m(j)$ are the contemporaneous residuals for the price of product j in other countries. As an example, we instrument for the price of the drug Sovaldi in the United States using the price residuals of Sovaldi in France, Germany, Canada, Spain, Italy, and the UK. The reason we use residuals as instruments is that these allow us to control for temporal, regional, and quality components that may contribute to contemporaneous demand-based variation in prices. We also allow for different relationships across countries for brand name drugs and generic drugs. We take additional care for producers with multiple drugs or for the fact that some drugs are available in only a subset of countries. When a product is not available in all other countries, we use residuals from available countries. When a product is available in only one country, we use the average residuals of other products within the same ATC in other countries as instruments. The main possible concern is that there is insufficient variation in these instruments to precisely identify price sensitivity, but this is again an empirical question of the power of instrumental variables, and we investigate this in our empirical estimates.

Finally, it is important to note that the estimation of BLP-type demand models requires the definition of market shares for products within each market. Quantities of drugs sold and normalized by standard units allow us to construct market shares but require the definition of a market size. Market sizes across many ATC-4 markets and across countries for the hospital sector are not obviously defined and can change over time and be very different. However, we do not observe an external estimate of market sizes, nor of the outside share (which would be equivalent). Instead, we approximate the aggregate yearly market size denoted by M_{mt} for each ATC-4 market using a nonlinear least squares calibration procedure similar to that in Huang and Rojas (2013, 2014). We describe this procedure in detail in Appendix 7.2.1. On average, we find that the estimated outside market share is 27.9% in Canada and 22.8% in the US with some variation across ATC-4 classes (see detailed estimates in Appendix 7.2.2).

3.3 Empirical Results on Demand Estimation

We present key estimated demand parameters for the US and Canada in Table 3.1. We find that the random coefficients on log prices in Canada and the US have similarly negative means. The standard deviation of the price coefficient in Canada shows substantial heterogeneity. There are a number of reasons that might underlie this. One of them is that price sensitivity may vary across hospital providers or for the same provider across patients with different disease severities and therefore willingness to pay for drugs. The random coefficient on generic preference can also represent heterogeneity in hospitals' purchasing policies and brand preferences. The random coefficient on the constant also the hospitals heterogeneity in drug intensity treatments.

We also find differences in the dimension of preference heterogeneity between Canada and the US. In the US, our estimate of the random coefficient on the generic indicator suggests that there is substantial heterogeneity in preferences for branded drugs. By contrast, in Canada, much of the heterogeneity in demand is captured in the constant term and is thus common to all drugs. We account for molecule fixed effects, ATC-4 specific year effects, and ATC-4 specific off-patent and generic effects as well, but do not report these in the Table for the sake of exposition.

Table 3.1: *Demand Estimates for US and Canada*

Country		US		Canada	
Log Price	α	-1.584	(0.10)	-1.273	(0.06)
	σ^{α}	0.028	(0.07)	-0.273	(0.13)
Generic Dummy	σ^{β}	0.126	(0.17)	3.313	(0.41)
Constant	σ^{γ}	0.891	(0.16)	0.102	(0.24)
Molecule dummies		Yes		Yes	
Off patent * ATC-4 dummies		Yes		Yes	
Generic * ATC-4 dummies		Yes		Yes	
Year * ATC-4 dummies		Yes		Yes	
Quarter dummies		Yes		Yes	

Note: Standard error in parenthesis. Models also contain dummy variables for ATC-4 specific year effects, and ATC-4 specific off-patent and generic effects. All dummy coefficients are not reported.

We present the average own- and cross-price elasticities for hospitals in the US and Canada in Table 3.2. These elasticities are computed using our estimated demand functions in every country, ATC-4 markets and quarters. We present the average elasticities across ATC-4 classes and quarters within each country, in aggregate and by branded status. Overall, average price elasticities are a bit higher in the US than in Canada. Own-price elasticities are slightly higher for branded than generics drugs in the US and similar in Canada. Table 7.3 in Appendix 7.3 shows those mean elasticities by ATC4 market, showing some variations across markets in own and cross price elasticities.

Table 3.2: *Average Price Elasticities for Canada and US*

	US		Canada	
	Own	Cross	Own	Cross
Branded	-1.512	0.133	-1.110	0.126
Generic	-1.376	0.147	-1.080	0.137
All	-1.430	0.142	-1.093	0.132

Note: Average own price elasticities across all products of ATC-4 markets and over quarters.

4 Supply Side Modeling and Estimates

4.1 Price setting with Bargaining in Separated Markets

We start by modeling price setting for pharmaceuticals in a regulated market with a Nash Bargaining model in which firms maximize profits, while government regulators maximize consumer welfare. We will use this model for Canada but it could apply typically to European countries or other regulated markets. Nash Bargaining models of this sort (see for instance, Crawford and Yurukoglu (2012); Grennan (2013); Gowrisankaran et al. (2015); Ho and Lee (2017); Dubois and Sæthre (2020)) provide a parsimonious way to characterize multiple bilateral negotiations and in particular the trade-offs facing policy-makers, who must balance producer profits against consumer welfare in each pairwise negotiations of prices with pharmaceutical firms. In Canada, this bargaining may be interpreted literally as the Canadian Patented Medicine Prices Review Board negotiates prices with drug manufacturers to ensure that they are not "excessive". Moreover, this model applies more generally to price-regulated pharmaceutical markets such as those in most European countries, when there is no international reference pricing. Currently, there is no international reference pricing linking the US market to other markets nor parallel trade of drugs between the US and countries (as there is within Europe, Dubois and Sæthre (2020)), this implies that drug pricing in the US is determined independently from other markets.

Firm profits are defined as follows. Within a market m at time t, firm f selling products $j \in F_{fm}$ receives flow profits:

$$\Pi_{fmt} \equiv \sum\nolimits_{j \in F_{fm}} \Pi_{jmt} \equiv \sum\nolimits_{j \in F_{fm}} (p_{jt} - c_{jt}) q_{jt}(\mathbf{p}_{mt}).$$

Here, c_{jt} and p_{jmt} are respectively the marginal cost and price of drug j. Their difference (the firm's markup) multiplies q_{jt}, the total quantity of drug j demanded in market m, given the vector of prices $\mathbf{p}_{mt} = (p_{1t}, .., p_{J_m t})$ of drugs available in the market. The quantity demanded is given by the size of the market M_{mt} multiplied by drug j's market share: $q_{jt} = M_{mt} s_{jt}$. Firm f's total profit is the sum of its profits across markets:

$$\Pi_{ft} \equiv \sum\nolimits_{m} \Pi_{fmt}.$$

We assume that government regulators maximize aggregate consumer welfare as revealed by the demand model in their country. We denote the welfare for consumers in market m at period

t by (Small and Rosen, 1981):

$$\begin{aligned} W_{mt}(\mathbf{p}_{mt}) &\equiv M_{mt}\int W_{imt}(\mathbf{p}_{mt})dF(\nu_{im};\theta) = M_{mt}\int \ln\left[1+\sum\nolimits_j \exp\left(u_{ijt}\right)\right]dF(\nu_{im};\theta) \\ &= M_{mt}\int \ln\left[1+\sum\nolimits_j \exp\left(\alpha_i \ln p_{jt} + \beta_{im} g_j + \gamma_i + \lambda_m x_{jt} + \phi_j + \mu_{mt} + \xi_{jt}\right)\right]dF(\nu_{im};\theta). \end{aligned} \tag{4.1}$$

That is, consumer welfare is given by the sum of the expected utility produced by each drug available in market m.

We assume that bargaining takes place market-by-market which amounts to a bargaining product-by-product because most companies hold a single product within an ATC-4 market. This implies that neither firms nor regulators are able to bargain jointly over their portfolio of pharmaceutical drugs across markets. This is made for simplicity as most firms own only one drug per ATC4 class and excludes the possibility of using bundling arrangements across ATC4 classes, while this is a testable extension left for future research.

Thus, at each market m and quarter t, prices are set product-by-product via Nash bargaining between the producer and the market m regulator, in order to maximize the Nash product of firm profits and consumer welfare. Denoting $\rho_{jm} \in [0,1]$ the bargaining parameter that determines the relative weight of the firm's (profit) objective in the Nash bargaining solution, we account for heterogeneity in the bargaining process across drug types by allowing ρ_{jm} to vary across ATC-4 markets and by each drug's status as on-patent, branded off-patent or generic. The Nash bargaining thus amounts for any j in market m to choose p_{jt} to maximize:

$$\underbrace{\left(\Delta_{jm}\Pi_{ft}\left(p_{jt},\mathbf{p}_{-jmt}\right)\right)}_{\text{Profit from } j \text{ in } m}^{\rho_{jm}} \underbrace{\left(\Delta_j W_{mt}(p_{jt},\mathbf{p}_{-jmt})\right)}_{\text{Welfare gain from } j \text{ in } m}^{1-\rho_{jm}}. \tag{4.2}$$

where $\mathbf{p}_{-jmt}$ denotes the vector of prices for all drugs other than j in market m and quarter t and the firm's objective is defined as the equilibrium additional profit generated by offering drug j at price p_{jt}, that is:

$$\Delta_{jm}\Pi_{ft}(p_{jt},\mathbf{p}_{-jmt}) \equiv \Pi_{ft} - \sum\nolimits_{j'\neq j, j'\in F_f} \Pi_{j'm(j')t} = \Pi_{jmt}(p_{jt},\mathbf{p}_{-jmt}),$$

Note that this is just the profit directly accrued from the sale of drug j, as most firms do not own several drugs per market. In the case where a firm owns several drugs within a market, Nash bargaining would then take into account substitution across the different drugs in their portfolios when setting prices.

Similarly, $\Delta_j W_{mt}(p_{jt}, \mathbf{p}_{-jmt})$ denotes the additional consumer surplus generated by the presence of drug j in market m and quarter t, that is:

$$\Delta_j W_{mt}(p_{jt}, \mathbf{p}_{-jmt}) \equiv W_{mt}(p_{jt}, \mathbf{p}_{-jmt}) - W_{mt}(\infty, \mathbf{p}_{-jmt}). \tag{4.3}$$

where $W_{mt}(\infty, \mathbf{p}_{-jmt})$ denotes by convention the welfare when j is absent of the market.

We assume a Nash-in-Nash equilibrium. That is, the vector of competitors' prices $\mathbf{p}_{-jmt}$, for competitors of j, in the case of agreement or disagreement are assumed to be equal to the equilibrium prices. Thus, the necessary first-order conditions of the Nash bargaining equilibrium definition in equation (4.2) imply that for all $j = 1, .., J_m$:

$$c_{jt} = p_{jt} + \frac{1}{\underbrace{\frac{\partial \ln q_{jt}(\mathbf{p}_{mt})}{\partial p_{jt}}}_{\text{Demand semi-elasticity}} + \frac{1-\rho_{jm}}{\rho_{jm}} \underbrace{\frac{\partial \ln \Delta_j W_{mt}(\mathbf{p}_{mt})}{\partial p_{jt}}}_{\text{Welfare semi-elasticity}}} \tag{4.4}$$

where

$$\frac{\partial \Delta_j W_{mt}(\mathbf{p}_{mt})}{\partial p_{jt}} = \frac{\partial W_{mt}(\mathbf{p}_{mt})}{\partial p_{jt}} = M_{mt} \int \frac{\partial W_{imt}(\mathbf{p}_{mt})}{\partial p_{jt}} dF(\nu_{im}; \theta) = M_{mt} \int s_{ijt} \frac{\partial u_{ijt}}{\partial p_{jt}} dF(\nu_{im}; \theta)$$

This pricing equation links the marginal cost to the demand and welfare price semi elasticities and shows that the equilibrium price should be increasing with the bargaining parameter ρ_{jm}. Note that when $\rho_{jm} = 1$, pricing is set according to an unrestricted Bertrand-Nash equilibrium in prices where firms maximize profits and (4.4) simplifies to the usual condition:

$$c_{jt} = p_{jt} + \frac{q_{jt}(\mathbf{p}_{mt})}{\partial q_{jt}(\mathbf{p}_{mt}) / \partial p_{jt}} \tag{4.5}$$

In such a case, an estimate of c_{jt} is straightforward to compute given demand parameter estimates. In the case of the US, we will use this special case to identify marginal costs, as we know that there is no central regulation of hospital prices akin to a bargaining game as in Canada. When $\rho_{jm} = 0$, we have price equal to marginal cost $p_{jt} = c_{jt}$. However, when ρ_{jm} is unknown, we face an identification issue to obtain marginal costs with the demand knowledge only but show next that adding marginal cost restrictions may allow us to identify both marginal costs and bargaining weights.

4.2 Supply Side Parameters Identification and Estimation

The set of first-order conditions (4.4) relates marginal costs to the shape of demand, drug prices, and the bargaining parameters ρ_{jm}. With known bargaining parameters, these first-order conditions allow us to identify the vector of marginal costs c_{jmt} as functions of ρ_{jm}.

As we noted before, in the US, we assume that $\rho_{jm} = 1$ because prices are freely chosen and not regulated for the hospital sector. [9] In that case, the first-order conditions simplify to the usual Bertrand-Nash first-order conditions (4.5) and allow identifying all marginal costs, which we denote c_{jUSt} for a product j in a market belonging to the US as in Nevo (2001). For generics in the US, for simplicity, we impose that prices equal to marginal costs and do not estimate margins, which is consistent with the typical fact that once many generics have entered, prices are low and close to marginal costs.

In Canada, prices are set through bargaining and so we must identify the bargaining parameters ρ_{jm} in addition to marginal costs using equations (4.4). Without any restriction on marginal costs or bargaining parameters, we cannot identify them jointly. We could use sign restrictions on marginal costs and markups in order to obtain lower and upper bounds on the bargaining parameter. However, it is natural to add restrictions based on parameterization to marginal costs functions as in Berry et al. (1995) and later papers (Dubois and Lasio, 2018). One way to identify costs and bargaining parameters is to let marginal costs be constant over time, constant across countries, or both. We assume that marginal costs can be parameterized as additively separable functions of supply-side covariates and an orthogonal error term as follows:

$$c_{jt}\left(\rho_{jm}\right) = z'_{jt}\lambda + \omega_{jt} \tag{4.6}$$

with

$$\mathbb{E}\left[z_{jt}\omega_{jt}\right] = 0 \tag{4.7}$$

and where $c_{jt}\left(\rho_{jm}\right)$ is solution of (4.4). In our application, z_{jt} include a molecule-specific and country-time-specific effect as well as the estimated US marginal cost c_{jUSt} from (4.5). We thus have further identification power by leveraging our assumption that pricing is known to be set through an unconstrained Bertrand-Nash pricing game for all products sold in the US.

[9] Notable exceptions to unconstrained pricing include pharmaceutical sales to the "Big Four:" Department of Veteran Affairs ($3.4 billion in 2003), Department of Defense ($4 billion in 2003), Public Health Service, and the Coast Guard, which receive discounted drug prices negotiated with manufacturers. Medicaid also receives effective discounts, but these are in the form of ex post rebates paid directly to the state rather than lower prices paid at the register. Medicare, on the other hand, is prohibited from negotiating prices.

The orthogonality conditions (4.7) allow to define for any market m in Canada and all j such that $m(j) = m$:

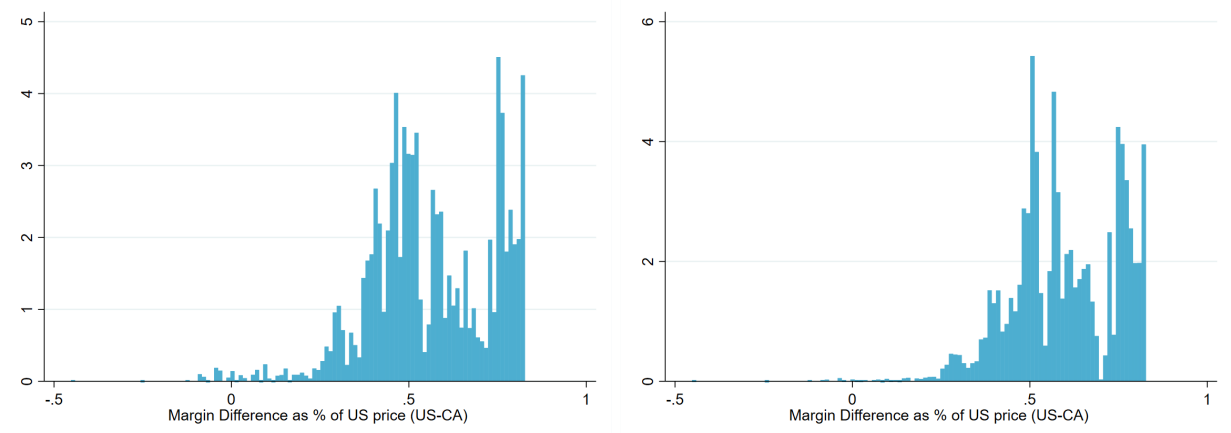
$$\omega_{jt}(\rho_{jm}) = \left[1 - z'_{jt}\left(z'_{jt}z_{jt}\right)^{-1} z'_{jt}\right] c_{jt}(\rho_{jm})$$

Thus, we solve for any ATC-4 class m in Canada:

$$\{\rho_{jm}\}_{\{j=1,..,J\}} = \arg \min_{\{\rho_{jm}\}_{\{j=1,..,J\}}} \sum_{j,t} \omega_{jt}^2(\rho_{jm}) \tag{4.8}$$

Table 7.6 in Appendix 7.4 shows the estimated average margins in percentage of the maximum average price of US and Canada (which is almost always the US) by ATC-4 class so that we can compare them across countries. The results show relatively large margins—which is not surprising in the case of pharmaceuticals. We also find that the margins are larger in the US than in Canada for most drugs. Figure 4.1 draws the distribution of the differences of margins between US and Canada as a percentage of the US price, weighting the distribution either by quantity sold in the US or in Canada. The difference is most often positive as very few drugs have higher margins in Canada than in the US. The graph shows that many of the products have margins in the US that are larger than in Canada by an amount that is more than 25% of the US price and up to 50%, which can mean extremely large differences in absolute values according to the US price level.

Figure 4.1: *Estimated Margins Differences between US and Canada for on Patent Drugs*



Note: The left panel shows the distribution of margins differences weighted by the US quantities of the drug. The right panel shows the distribution of margins differences weighted by the Canadian quantities of the drug. These distributions are for the sample of on-patent drugs present in both the US and Canada.

The supply model estimates also provide bargaining parameters estimates for Canada, as shown in Table 7.5 in Appendix 7.4. The parameters vary between 0 and 1.

5 Counterfactual Policies

In this section, we apply our structural model to evaluate the impact of a counterfactual international reference pricing policy on equilibrium prices, expenditures and welfare.

A discussion before the US congress on an international reference pricing policy was first introduced by the H.R.3. Lower Drug Costs Now Act in 2019 and very recently reintroduced under the H.R. 5376 Building Back Better Act. There rules would basically not allow prices in the US for an on-patent drug to be higher than an Average International Market price using prices in Australia, Canada, France, Germany, Japan, and the UK.

Our baseline counterfactual considers a reference pricing rule (also referred to as a "most favored nation" clause) that prohibits pharmaceutical companies from setting higher prices for on-patent drugs in the United States than in Canada. Proponents of reference pricing policies, such as the H.R.3. Lower Drug Costs Now Act that was introduced before the US Congress in 2019 and very recently reintroduced under the H.R. 5376 Building Back Better Act, argue that reference pricing will decrease U.S. prices by forcing them down to match Canada's. But there is no guarantee that Canadian prices will remain at the same low level once the market re-equilibrates.

To predict counterfactual prices, we extend our model of price setting from Section 4.1 to impose reference pricing in the bargaining between pharmaceutical firms and Canadian authorities. Under reference pricing, any on-patent drug that is sold at a lower price in Canada cannot be sold in the U.S. (yielding 0 profits from the US to the firm). Since firms simultaneously set U.S. prices and negotiate in Canada, the equilibrium prices in the U.S. and Canada do come together—but, as we show theoretically in Appendix 7.5, they typically meet at a level that is closer to the higher initial U.S. price. The extent to which prices in the U.S. fall and the resulting consumption, expenditure and welfare in each country increase or decrease is an empirical question, governed by our parameter estimates from Sections 3.3 and 4.2.

We also consider several extensions of our baseline model to disentangle the forces that impact the result of reference pricing and approximate the types of policies that are being actively discussed in legislation. In particular, we consider counterfactuals in which the referenced country is larger than Canada in market size, in which an *index* of multiple countries is used for referencing instead of one country, and in which a small price premium in the U.S. relative to the referenced country is allowed. In each case, we find that equilibrium savings to U.S. consumers are small relative to the status quo price difference, although referencing more and larger countries is often helpful. A key reason is that the U.S. market is unrivaled in its size, and so drives negotiations in the referenced country rather than the other way around. To understand how prices would look if

instead the U.S. was able to leverage its size in negotiations, we consider a counterfactual in which the U.S. is able to bargain directly with pharmaceutical firms (without reference pricing), and consider a stronger form of reference pricing rules, including the conditioning that the reference country accepts the price agreement in order to sell in the US, that would empower negotiators in the referenced country to bargain on the U.S.'s behalf.

5.1 Counterfactual Policies Definitions

5.1.1 International Reference Pricing with respect to Canada

International reference pricing as considered for policy would apply only for on-patent drugs and would require that for drug j sold in both the United States (US) and Canada (CA) the equilibrium prices satisfy:[10]

$$p_j^{US} \leq p_j^{CA}. \tag{5.1}$$

As this constraint is not satisfied in the status quo environment, reference pricing acts to connect price setting in the two countries: demand pressures in one country impact price setting in the other. Interconnected price setting has been shown to induce externalities on availability and consumption in other contexts. For instance, (Danzon and Chao, 2000; Danzon et al., 2005; Maini and Pammoli, 2017) demonstrate that pharmaceutical firms employ strategic delays in introducing their products to different European countries in order to relax the constraints of reference pricing rules across Europe. In our context, it is likely that the reference pricing constraint will be especially salient: the U.S. market is approximately 10 times bigger than Canada's, and three times bigger than the biggest market (Japan) included in the price index of HR3 and H35376. It is thus likely that pharmaceutical firms would comply with reference pricing by adjusting their price setting in the referenced country as well as in the US (rather than accept massive losses from price changes in the U.S. alone). We assume that firms jointly optimize their price setting across countries so as to maximize their overall profit subject to the reference pricing constraint. We do not account for country level differences in taxation on corporate profits because corporate tax rates are similar between the US and referenced countries being considered (OECD Corporate Tax Statistics 2021, https://www.oecd.org/tax/tax-policy/corporate-tax-statistics-third-edition.pdf).[11]

The international reference pricing rule creates externalities across countries and a sort of intra-brand competition between sales in the US and the reference country, such that the price

[10] To simplify notation, we exclude the time and drug-class subscripts in this section.

[11] Of course, tax rates may need be taken into account in other applications, in which case the objective function of the firm should be to maximize the profits net of each country specific taxes.

competition in the US need account for the referencing. Thus, we first introduce the reaction function by which firms set their U.S. prices, given both the price of competing products in the U.S. and the price of the same product in Canada. This reaction function captures the reference pricing rule as a constraint on the firm's profit maximization problem. For a given price p_j^{CA} that determines the firm's profit from Canada, the firm either maximizes its U.S. profits over the restricted domain of prices below p_j^{CA} or chooses not to sell in the U.S. at all. As in Section 4, we use $p_j^{US} = \infty$ to denote exit from the U.S. market. This can be an equilibrium outcome for a given ATC drug market class when the Canadian market is large, Canadian consumers are price sensitive or marginal cost is very low relative to the U.S. so that the firm prefers eventually to sell large quantities at a too low price in Canada for the same price to be profitable in the U.S. Formally, firm j's U.S. reaction function can be written as:

$$p_j^{US}(p_j^{CA}, \mathbf{p}_{-j}^{US}) \equiv \arg \max_{p \in [0, p_j^{CA}] \cup \{\infty\}} \Pi_j^{US}\left(p, \mathbf{p}_{-j}^{US}\right) \mathbf{1}_{\{p \leq p_j^{CA}\}}. \tag{5.2}$$

Next, we redefine negotiations between pharmaceutical companies and the Canadian regulator to account for the international reference pricing policy. Given a negotiated price p_j^{CA} in Canada, firm j expects to earn $\Pi_j^{CA}(p_j^{CA}, \mathbf{p}_{-j}^{CA})$ in Canada and $\Pi_j^{US}(p_j^{US}(p_j^{CA}, \mathbf{p}_{-j}^{US}), \mathbf{p}_{-j}^{US})$ in the U.S., where $p_j^{US}(p_j^{CA}, \mathbf{p}_{-j}^{US})$ is computed by Equation (5.2). Firm j's profit from agreeing to a price of p_j^{CA} in Canada is therefore given by:

$$\begin{aligned}\Delta\Pi_j(p_j^{CA}, \mathbf{p}_{-j}^{US}, \mathbf{p}_{-j}^{CA}) \equiv \; & \underbrace{\Pi_j^{US}(\overbrace{p_j^{US}(p_j^{CA}, \mathbf{p}_{-j}^{US})}^{\text{US price reaction}}, \mathbf{p}_{-j}^{US}) + \Pi_j^{CA}(p_j^{CA}, \mathbf{p}_{-j}^{CA})}_{\text{global profit under agreement}} \\ & - \underbrace{\Pi_j^{US}(\overbrace{p_j^{US}(\infty, \mathbf{p}_{-j}^{US})}^{\text{US price without constraint}}, \mathbf{p}_{-j}^{US})}_{\text{profit if in US only}}.\end{aligned}$$

Note that firm j's profit in other countries does not affect this surplus as price setting in countries outside the reference pricing policy's reach is independent of prices in the U.S. and Canada.

Following Horn and Wolinsky (1988), the negotiated price in Canada is given by the maximizer of the Nash product:

$$p_j^{CA}(\mathbf{p}_{-j}^{US}, \mathbf{p}_{-j}^{CA}) \equiv \arg\max_p \left(\underbrace{\Delta\Pi_j(p, \mathbf{p}_{-j}^{US}, \mathbf{p}_{-j}^{CA})}_{\text{profit gain from agreement}} \right)^{\rho_j} \left(\underbrace{\Delta_j W_{CA}(p, \mathbf{p}_{-j}^{CA})}_{\text{welfare gain from agreement in CA}} \right)^{1-\rho_j}. \tag{5.3}$$

Thus, in equilibrium, prices for on-patent drugs sold in the United States and Canada are jointly defined by Equations (5.2) and (5.3).[12] In other words, equilibrium prices $\{(p_j^{US*}, p_j^{CA*})\}_j$ for each firm j, are characterized by:

$$\begin{aligned} p_j^{US*} &= p_j^{US}(\mathbf{p}_j^{CA*}, \mathbf{p}_{-j}^{US*}), \\ p_j^{CA*} &= p_j^{CA}(\mathbf{p}_{-j}^{US*}, \mathbf{p}_{-j}^{CA*}). \end{aligned} \tag{5.4}$$

In Appendix 7.5, we show—under mild assumptions on the concavity of each firm's profit in its own price and strategic complementarity in prices across firms—that U.S. prices must (weakly) decrease and Canadian prices increase in any equilibrium where the solution to Equation (5.1.3) is interior and no firms exit the market. However, the effectiveness of a reference pricing policy toward curbing expenditures in the U.S. depends crucially not just on the direction, but also on the magnitude of price variations across countries and subsequent changes in domestic consumption.

5.1.2 Variations of Reference Pricing Rules with Respect to Canada

Our baseline model of international reference pricing imposes several assumptions that may not be implemented exactly as is. First, we assume that reference pricing is exact: the price of a drug in Canada is a tight upper bound on the price in the US. A common alternative policy, often referred to as a "Most Favored Nation" clause would link the prices in the U.S. and reference but allow a limited gap in between them. For example, H.R. 3 and H.R. 5376 consider a 20% additional premium over an average international market price. To see how this might change our results, we consider a modification of our reference pricing model in which the price constraint is instead written as:

$$p_j^{US} \leq (1+\eta) p_j^{CA} \tag{5.5}$$

where η is the maximum premium above the Canadian price that is allowed in the U.S.

Whereas a "Most Favored Nation" clause is a relaxation of the reference pricing policy, we also consider a strengthening. Our baseline model assumes that firms may choose not to sell a drug in the reference country (Canada) if they would prefer to avoid the reference pricing constraint in the U.S. market. This implies that the disagreement payoff of a firm negotiating in Canada is given by the unconstrained maximum profit in the U.S. market (and zero in the Canadian market). An alternative policy might instead require that drug manufacturers continue selling any drug that had previously been offered in the reference country in order to also sell it

[12] The usual profit maximization and Nash bargaining conditions must also be satisfied for all other products in the US and Canada.

in the U.S. This is a very strong constraint, as it implies that finding an agreement in Canada is necessary for selling in the U.S.—and that the agreed upon price will serve as reference price for the US.

In this case, the Nash surplus of the firm negotiating over the price of drug j in Canada becomes:

$$\Delta\Pi_j(p_j^{CA}, \mathbf{p}_{-j}^{US}, \mathbf{p}_{-j}^{CA}) = \Pi_j^{US}(p_j^{US}(p_j^{CA}, \mathbf{p}_{-j}^{US}), \mathbf{p}_{-j}^{US}) + \Pi_j^{CA}(p_j^{CA}, \mathbf{p}_{-j}^{CA}).$$

In effect, this "required comparison" constraint provides the Canadian regulator with the ability to directly negotiate a price for both the Canadian and U.S. markets. The firm's disagreement payoff when negotiating with the Canadian regulator becomes zero (because of zero profits in both countries), giving the regulator substantially more leverage to obtain a lower price for both in equilibrium. As such, a "required comparison" policy may seem highly desirable from a U.S. perspective. But this entails a very strong commitment on behalf of U.S. consumers: it requires that the U.S. market be willing to reject innovative drugs that can save lives and improve welfare on the basis of bargaining decisions made by an unaccountable Canadian regulator. It would mean that the US would not accept innovative drugs that are not reimbursed by the reference country, thus abandoning fast access to innovation. It would also mean that price levels are determined by the welfare gain those drugs bring to reference countries with possibly very different health care priorities because of different needs and diseases prevalence. Given the scale of the U.S. market, it might be more plausible for the U.S. to instead negotiate on behalf of its own consumers without appealing to Canadian regulators at all. We detail this case in Section 5.1.4.

5.1.3 International Reference Pricing with respect to a set of Countries

Although our baseline counterfactual considers reference pricing with respect to one country, many policies being considered in practice instead refer to an index of multiple countries. In order to account for this possibility, we consider the model where the U.S. requires the price of each on-patent drug to be weakly lower than its average price across a set of countries $\mathcal{C}$ in which the product is sold:

$$p_j^{US} \leq \overline{p_j^{\mathcal{C}}} \equiv \frac{\sum_{c \in \mathcal{C}} p_j^c 1_{\{j \text{ is in } c\}}}{\sum_{c \in \mathcal{C}} 1_{\{j \text{ is in } c\}}}. \tag{5.6}$$

For example, Title I of the H.R.3. Lower Drug Costs Now Act and Title XIII subtitle J of H.R. 5376 Build Better Back Act propose a price index reference rule using an average of six countries prices (Australia, Canada, France, Germany, Japan, UK). As in Equation 5.2, the U.S. reaction

to a given a reference price index is characterized by:

$$p_j^{US}(\overline{p_j^{\mathcal{C}}}, \mathbf{p}_{-j}^{US}) \equiv \arg \max_{p \in [0, \overline{p_j^{\mathcal{C}}}] \cup \{\infty\}} \Pi_j^{US}\left(p, \mathbf{p}_{-j}^{US}\right) \mathbf{1}_{\{p \leq \overline{p_j^{\mathcal{C}}}\}}$$

Assuming that bargaining in all referenced countries occurs simultaneously, the price negotiation with each reference country c of firm j must satisfy:

$$\max_{p_j^c} \quad \Delta\Pi_j(p_j^c, \mathbf{p}_{-j}^{US}, \mathbf{p}_{-j}^c, \overline{p_j^{\mathcal{C}}})^{\rho_j} \Delta_j W_c(p_j^c, \mathbf{p}_{-j}^c)^{1-\rho_j}$$

where the Nash surplus of firm j's total profit from agreeing with country c and internalizing the reference pricing constraint in the US is:

$$\Delta\Pi_j(p_j^c, \mathbf{p}_{-j}^{US}, \mathbf{p}_{-j}^c, \overline{p_j^{\mathcal{C}}}) \equiv \underbrace{\Pi_j^{US}(\overbrace{p_j^{US}(\overline{p_j^{\mathcal{C}}}, \mathbf{p}_{-j}^{US})}^{\text{US price reaction}}, \mathbf{p}_{-j}^{US}) + \Pi_j^c(p_j^c, \mathbf{p}_{-j}^c)}_{\text{global profit under agreement}} - \underbrace{\Pi_j^{US}(\overbrace{p_j^{US}(\overline{p_j^{\mathcal{C}\setminus c}}, \mathbf{p}_{-j}^{US})}^{\text{US price reaction}}, \mathbf{p}_{-j}^{US})}_{\text{profit if in US only}}.$$

Here, $\overline{p_j^{\mathcal{C}\setminus c}}$ denotes the average price of drug j in reference countries other than c. Note that the profits of countries other than the US and c do not appear in the firm's negotiation with c. This is because in a Nash equilibrium among all countries the profits in other countries cancel out of the Nash surplus with country c. But, of course, equilibrium prices in other countries matter for overall profits. Under the indexed international reference pricing rule, equilibrium prices $\{(p_j^{US*}, p_j^{c*})\}_{j,c}$ must satisfy the following conditions for all j and all $c \in \mathcal{C}$:

$$p_j^{US*} = p_j^{US}(\overline{p_j^{\mathcal{C}}}^*, \mathbf{p}_{-j}^{US*})$$
$$p_j^{c*} = p_j^c(\mathbf{p}_{-j}^{US*}, \mathbf{p}_{-j}^{c*}, \overline{p_j^{\mathcal{C}}}^*)$$

Although we do not estimate supply and demand for all six countries being considered in the HR3 and HR5376 bills (Australia, Canada, France, Germany, Japan, UK), we simulate the indexed international reference pricing equilibria with varying number of replicas of Canada. Adding more countries to the index gives regulators more leverage over pharmaceutical firms, as exiting one country does not allow firms to evade the reference pricing constraint. Our simulations therefore highlight the impact of additional reference countries on driving lower equilibrium prices across different ATC-4 markets.

5.1.4 National Bargaining in the US

We also consider a US bargaining equilibrium with a varying bargaining weight ρ_{jUS} for an hypothetical US national regulator who would negotiate prices using the US consumer surplus as objective function. The advantage of such policy is that it is independent of other countries pricing behavior and allows accounting for US priorities in health care when measuring the welfare benefit of a medicine treatment on US patients welfare. This counterfactual policy is then simply the solution of the following Nash in Nash bargaining equilibrium:

$$\underbrace{\left(\Delta_{jUS}\Pi_{ft}\left(p_{jt}, \mathbf{p}_{-jUSt}\right)\right)}_{\text{Profit from } j \text{ in } US}^{\rho_{jUS}} \underbrace{\left(\Delta_j W_{USt}(p_{jt}, \mathbf{p}_{-jUSt})\right)}_{\text{Welfare gain from } j \text{ in } US}^{1-\rho_{jUS}} \tag{5.7}$$

where $\mathbf{p}_{-jUSt}$ denotes the vector of prices for all drugs other than j in the US and quarter t and the firm's objective is defined as the equilibrium additional profit generated by offering drug j at price p_{jt}, that is:

$$\Delta_{jUS}\Pi_{ft}(p_{jt}, \mathbf{p}_{-jUSt}) \equiv \Pi_{ft} - \sum\nolimits_{j' \neq j, j' \in F_f} \Pi_{j'm(j')t} = \Pi_{jUSt}(p_{jt}, \mathbf{p}_{-jUSt})$$

and $\Delta_j W_{USt}(p_{jt}, \mathbf{p}_{-jUSt})$ is the welfare gain obtained from the purchase of drug j coming from the revealed demand preferences at price p_{jt}, and defined similarly as in equations (4.1) and (4.3).

5.2 Counterfactual Simulations

Using our estimates for the parameters governing supply and demand from sections 3 and 4, we simulate the counterfactual equilibria under each policy considered above. Although the reference constraint applies only to patented drugs, the pricing decisions for generic and branded off-patent drugs are also affected in equilibrium since their optimal pricing may change when on-patent competing molecules change prices. In each case, we examine the effects on equilibrium prices in both the U.S. and Canada, as well as the effects on total expenditures, consumer welfare and cross-country profits for firms. As the policy does not bind when there is no on-patent drug within an ATC-4 class in both the US and Canada, we consider only the ATC-4 classes that have at least one drug still on patent in both countries.

5.2.1 Reference Pricing Canada

We first examine our baseline reference pricing policy. We compute counterfactuals for each ATC-4 class independently, since ATC-4s correspond to our market definition of drugs in the hospital sector.

Starting with on-patent drugs, Table 5.1 shows the average price effects of the international reference pricing rule by ATC-4 class. The reference pricing rule for on patent drugs is in general a binding price constraint (i.e., $p_j^{US} = p_j^{CA}$) leading to small price decreases in the US and large price increases in Canada. Depending on the class, the effect on prices of patented drugs in the US ranges from 0 to -29.72% but on average across ATC-4 classes it is -7.54% only. Moreover, as we will see later, this is the effect on patented drugs, which leads to a smaller effect on average because generic drugs prices decrease by even less. On the contrary, prices go up in Canada quite importantly, and sometimes more than ten fold, with an average increase of 215.99% across these ATC classes. Thus, the international reference pricing policy when applied by referring to Canada only, would result in a large price increase for drugs in Canada and a small price decrease in the US. This is because prices are much higher in the US than in Canada and the externality link across countries imposed by the reference pricing policy imports the unregulated high prices in the US to Canada rather than the reverse because the US market is much larger and profitable. It is clearly much more costly for firms to reduce the US price by one dollar than increase the Canadian price by one dollar. The international reference pricing policy that would consider only the reference to Canada would thus result in small effects in the referring country but very large ones in the referenced one, something that is clearly not intended by the policy makers' proposal to introduce this rule. Of course the policy proposal recommends using the average price from six reference countries which may reduce the price inflating impact in reference countries and help lower the US price, which we will examine below.

Table 5.1: *Counterfactual Prices of on Patent Drugs when International Reference Pricing w.r.t. Canada*

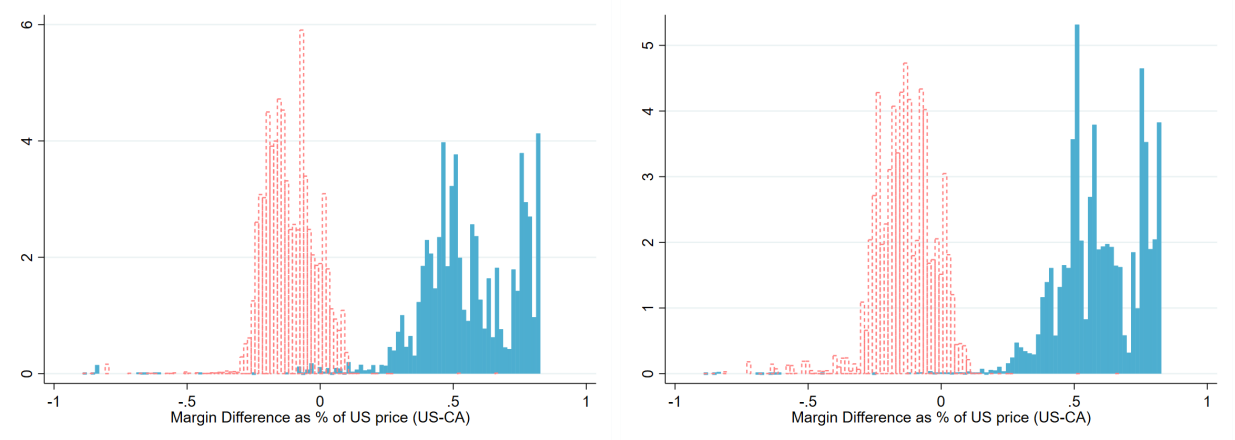
	Before		After			
	Canada	US	Canada		US	
ATC4	Price	Price	Price	Δ (%)	Price	Δ (%)
A10H0	0.63	1.03	1.03	62.58	1.03	-0.03
C2A2	57.76	17.32	57.76	0.00	17.32	0.00
C7A0	1.08	1.95	2.04	88.84	1.95	-0.40
C8A0	1.06	2.19	2.12	99.71	2.12	-3.34
C9A0	0.55	1.78	1.40	154.08	1.40	-21.18
L1B0	247.97	506.81	429.14	73.06	429.14	-15.33
L1X9	545.32	579.99	593.76	8.88	570.61	-1.62
L4X0	4.98	10.03	8.47	69.92	8.25	-17.70
M1A1	0.67	3.07	2.16	220.97	2.16	-29.72
N1A2	21.11	51.54	49.59	134.92	49.59	-3.78
N1B1	12.56	16.47	16.42	30.74	16.42	-0.30
N3A0	1.55	3.79	3.72	139.40	3.72	-1.71
N5A1	2.75	13.51	12.24	345.22	12.24	-9.43
N5A9	0.82	1.36	1.33	60.96	1.33	-2.51
N5B3	2.67	61.87	52.46	1863.08	52.46	-15.21
N6A4	1.53	3.68	3.61	135.45	3.61	-1.90
N6A9	0.39	1.15	1.10	184.14	1.10	-4.10
Unweighted Mean				215.99		-7.54

Note: Market shares weighted average price of patented drugs by ATC-4 and country for drugs present in both only. Percentage changes are changes with respect to the initial situation. Unweighted mean is mean across ATC4 of the percentage price change.

Analogously to Figure 4.1, Figure 5.1 shows the difference for on patent drugs margins in the United States and Canada both in the baseline and under the reference pricing counterfactual. This figure shows that the international reference pricing policy results in generally higher margins in Canada than in the United States, the reverse of what we find in the baseline without reference pricing.[13]

[13]The left graph of Figure 5.1 shows that when weighting the distribution by the US quantities of each drug, a significant number of on-patent drugs will exhibit higher margins in Canada. The right graph of Figure 5.1 shows that the share of drugs with substantially higher Canadian margins is amplified when weighting by Canadian quantities.

Figure 5.1: *Current and Counterfactual Margins Differences for on Patent Drugs*



Note: The empirical distribution of the difference between margins in Canada and the US, $(p^{CA} - c^{CA}) - (p^{US} - c^{US})$*, normalized by each drug's US price and weighted by the quantity of the drug sold in the US (left) and in Canada (right). The dotted distribution is the counterfactual while the solid one is the estimated current distribution.*

These graphs show that, while the status quo margins are larger in the US, then international reference pricing will make the margins higher in Canada for a substantial quantity of on-patent drugs. Despite the fact that prices of on patent drugs present in both countries will equalize in equilibrium, this occurs become marginal costs are often higher in the US than in Canada.

We now look at the effects of the policy on expenses and firms' profits. These effects account not only for the fact the demand elasticity attenuates price effects on expenses but also for the full equilibrium effects on all drugs within an ATC-4 classes, including on patent drugs subject to the reference pricing constraint but also off patent branded and generic ones.

Table 5.2 shows the changes in expenses in each country resulting from the new price equilibrium when an International Reference Pricing is implemented. Variations across ATC classes can be large but effects are clearly much larger in Canada than in the US where expenses decrease very little on average by 5.53% and a maximum decrease of 18.54% for the Anti Cancer class of antimetabolites. On the contrary in Canada, expenses would grow overall for these ATC classes by 41.74%.

Table 5.2: *Counterfactual Expenses Changes on All Drugs when International Reference Pricing w.r.t. Canada*

	Canada			US		
ATC4	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	392	392	-0.0	11065	11065	0.0
C2A2	1468	1468	0.0	34117	34117	0.0
C7A0	3027	3042	0.5	134842	134827	-0.0
C8A0	12454	14306	14.9	240970	237764	-1.3
C9A0	8646	11361	31.4	52300	52116	-0.4
L1B0	32322	52268	61.7	408366	332673	-18.5
L1X9	28033	28797	2.7	201395	200119	-0.6
L4X0	58224	83548	43.5	478261	433363	-9.4
M1A1	1666	1703	2.2	26388	26638	0.9
N1A2	23090	24018	4.0	602738	603092	0.1
N1B1	6434	6578	2.2	114498	114519	0.0
N3A0	11284	11477	1.7	436053	435938	-0.0
N5A1	70817	125231	76.8	966348	888415	-8.1
N5A9	2584	2586	0.1	51089	51084	-0.0
N5B3	138	145	4.8	5856	6118	4.5
N6A4	6018	6960	15.6	143410	142491	-0.6
N6A9	2509	2517	0.3	54167	54163	-0.0
Total	247648	351009	41.74	3527247	3332173	-5.53

Note: Expenses are average yearly expenses in 1000 US$ (from the period 2002-2013). Δ stands for the change in expenses between after and before in percentage of initial expenses.

Finally, Table 7.10 in Appendix shows that these changes would lead to a slight increase in profits overall as the decrease in profits in the US market would be close but slightly less than the increase in profit in Canada.

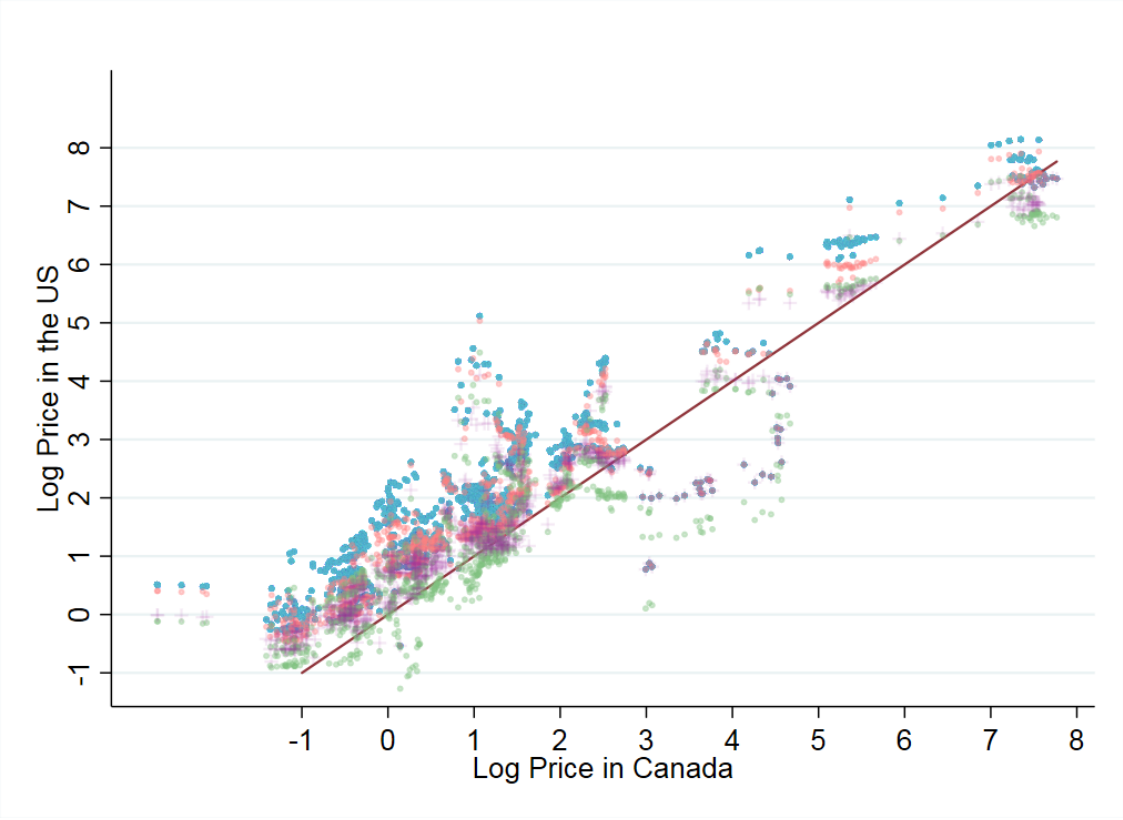
5.2.2 Comparison of the various Counterfactual Policies

We now examine the counterfactual results of the different counterfactual policies like the International Reference pricing with more than one country in the reference group, the international reference pricing with required comparison, the international reference pricing with a price premium allowed in the US and the hypothetical US bargaining policy.

Figure 5.2 shows the set of all on patent drugs prices in the US and in Canada under the statu quo, the IRF with six countries, the IRF with required comparisons and the US bargaining. The figure shows the level of the equilibrium US and Canadian price of these on patent drugs on the vertical axis as a function of the ex ante Canadian prices on the horizontal axis. In the case of the statu quo ex ante distribution, the figure shows the position of US prices on vertical axis as function of Canadian prices on horizontal axis. In the case of the US bargaining, as Canadian prices would no be affected, the scatter plot represents the US prices after bargaining

on the vertical axis as a function of the same drug price in Canada on the horizontal axis. The statu quo distribution of prices shows that ex ante the US prices are indeed above those in Canada for the same drugs. The figure also shows the distribution of those prices in the US after implementing a reference pricing policy with six counties as reference. It shows that prices of these on patent drugs will equalize in both countries to levels in between the ex ante lower Canadian price and ex ante higher US price. As will be shown below, the 6 countries reference pricing policy allows to lower more the US prices and increase less the Canadian price than referring to a lower number of countries. The figure also shows the international reference pricing with required comparison that lowers more the price in the US and increase them less in Canada. The figure shows finally the US bargaining that does not change the Canadian prices but shows that it lowers substantially the US prices often to lower levels than the Canadian prices, because the US bargaining allows leveraging the US market size and characteristics (including the fact that it has in general more products on market).

Figure 5.2: *Price Comparisons under Counterfactual Policies*

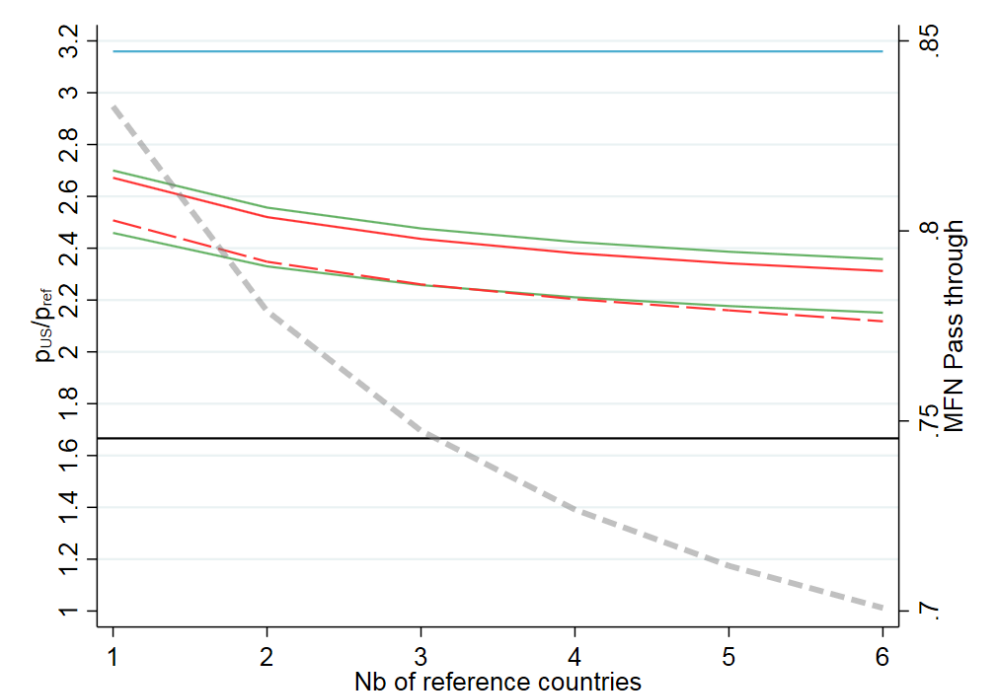


Note: Scatter plots of US prices versus Canadian prices for on patent drugs for the counterfactual equilibrium of International Reference Pricing with respect to one country, or six countries, or one country of the US size or with US directly bargaining the prices of drugs. ● *Statu quo* ● *IRF with six countries* ● *US bargaining + IRF with required comparison*

Then, looking at the changes in average price difference between countries, Figure 5.3 shows these ratio under the various international reference pricing policies and varying number of countries in the reference from 1 to 6. The statu quo ratio is the value of the average price ratio between the US and Canada as during the period 2002 to 2013 for on patent drugs only present in both countries. It shows that the price ratio is on average around 1.4. Then, the graph shows that implementing the International Reference Pricing with respect to Canada alone leads for on patent drugs to a decrease of US prices and an increase of Canadian prices such that the new price (equal in both countries for on patent drugs) is on average 1.3 times the initial price in Canada. This means a large price increase in Canada with a somewhat much smaller decrease in the US. Adding more countries to the reference countries allows to reduce the equilibrium price in the US and increase a bit less the one in the reference countries but the effect is not important compared to the international reference pricing with required comparison that lowers the equilibrium price to be around 1.2 times the initial Canadian price. The figure also shows that referencing to larger countries than Canada, for example with Canada being half the US size (instead of one eighth) does not importantly change the equilibrium prices. However, looking in more details by ATC4, one can observe in Figure 7.2 in appendix that the reference pricing referring to larger external markets tends to make the price decrease in the US larger and the price increase in referred countries smaller. Indeed in that figure we find that the effect of referring to a representative country being half the size of Canada is smaller than to referring to Canada only for the markets (ATC classes) that represent in Canada already more than half of the US size (namely the following ATC4 classes: L1B0, L1X9, L4X0, N5A1). This confirms that referring to larger size countries allows a higher reduction of prices in the US while making the increase in the reference country larger.

Then, we also examine the MFN premium rule effect on equilibrium. Allowing a 10% price premium on the MFN rule leads to higher prices in the US than with the standard reference pricing not allowing a price premium in the US. With a 10% price premium, one can see that a share of .83 of the 10% price premium goes into a reduction of the Canadian price versus an increase of the US price compared to the no premium equilibrium case. However, this pass trough of the 10% premium becomes smaller when the number of reference countries increases going down to .70 with six countries.

Figure 5.3: *Relative Drugs Prices: US vs Canada under Different Counterfactual Policies*



Note: Average of ratios of prices of on patent drugs present in both countries across all classes between the US and the Reference Country under the different counterfactuals. The two lines — represent the average ratio of US equilibrium price over initial Canadian price and the one of the Canadian equilibrium price over initial Canadian price in the case of IRF with 10% MFN. - - MFN pass through in Canada with vertical scale on the right
— Statu quo — IRF – – IRF with Reference Half US Size — IRF with 10% MFN – IRF with required comparison

Table 5.3 shows equilibrium changes in expenses in the US and the reference country or countries under each policy. The changes in expenses vary across ATC classes and whatever the class we observe that the price changes result in increased expenditures in Canada and decreases in the US (with few exceptions). Comparing the International Reference Pricing expenses when referring to one country instead of six, we observe that expenses increase less in Canada, the representative reference country, when referring to six countries instead of one, while they decrease more in the US. The international reference pricing with required comparison results in smaller increase of expenses in Canada and larger decrease in the US. Finally the US bargaining equilibrium, while not changing expenses in the reference country, leads sometimes to larger decreases in expenses and sometimes to smaller decrease but overall the US bargaining performs better in reducing expenses in the US than the different reference pricing policies and even than the international reference pricing with required comparison, even though it is not uniform across classes. The reason the US bargaining leads to sometimes larger expenses than the International Reference Pricing with required comparison comes from the fact that in one case

the price setting depends on the US consumer welfare in the Nash-in-Nash bargaining equilibrium while in the other case it depends on the Canadian bargaining and Canadian consumer welfare.

Table 5.4 shows the counterfactual profits of firms under each policy. It shows that with a larger number of countries in the reference set, profits would increase less in Canada and decrease more in the US. In the case of international reference pricing with required comparison, profits would decrease even more in the US and increase less in Canada in each country. With bargaining the profits in the US would decrease more than with any other policy.

Then Table 5.5 shows the overall profit that the pharmaceutical firms would make in the US and the six representative countries such as Canada depending on whether the US implements an international reference pricing with respect to one other country or six other countries or an international reference pricing policy with required comparison, or if the US implements an internal bargaining of drugs prices without external referencing. The results of profit change in the US and Canada being opposite, the overall effect appears to be close to zero when the international reference pricing applies to one external country only. However when referring to six countries, the profits increases obtained in the referred countries more than compensate the decrease of profits in the US such that overall profits would increase by 2.21 %.

Table 5.3: *Counterfactual Expenses Changes on All Drugs*

	Canada				US				
		Int. Ref. Pricing				Int. Ref. Pricing			
ATC4	Before	(N=1) Δ (%)	(N=6) Δ (%)	Comparison Δ (%)	Before	(N=1) Δ (%)	(N=6) Δ (%)	Comparison Δ (%)	Bargaining Δ (%)
A10H0	392	-0.0	-0.0	-0.0	11065	0.0	0.0	-0.1	-7.0
C2A2	1468	0.0	0.0	0.0	34117	0.0	0.0	0.0	7.9
C7A0	3027	0.5	0.5	0.4	134842	-0.0	-0.1	-0.7	-7.8
C8A0	12454	14.9	12.4	3.8	240970	-1.3	-6.1	-20.6	-68.9
C9A0	8646	31.4	24.0	19.4	52300	-0.4	-2.2	-7.6	-9.7
L1B0	32322	61.7	48.1	30.1	408366	-18.5	-25.1	-32.4	-18.7
L1X9	28033	2.7	1.7	-10.8	201395	-0.6	-1.1	1.6	6.2
L4X0	58224	43.5	20.7	21.3	478261	-9.4	-23.0	-22.4	-40.7
M1A1	1666	2.2	2.1	1.9	26388	0.9	1.5	2.3	1.9
N1A2	23090	4.0	3.8	3.2	602738	0.1	0.2	2.7	3.4
N1B1	6434	2.2	2.1	0.6	114498	0.0	0.1	0.9	0.3
N3A0	11284	1.7	1.5	1.3	436053	-0.0	-0.2	-1.7	-4.8
N5A1	70817	76.8	50.4	21.5	966348	-8.1	-19.6	-38.5	-41.3
N5A9	2584	0.1	0.1	0.1	51089	-0.0	-0.0	-0.1	-0.5
N5B3	138	4.8	4.8	2.2	5856	4.5	4.4	33.6	19.5
N6A4	6018	15.6	13.7	10.7	143410	-0.6	-3.0	-7.7	-21.4
N6A9	2509	0.3	0.3	0.3	54167	-0.0	-0.0	0.2	-0.3
Total		41.74	26.78	14.65	3527247	-5.53	-11.46	-17.53	-21.15

Note: Expenses are average yearly expenses in 1000 US$ (from the period 2002-2013). Δ stands for the change in expenses between after and before in percentage of initial expenses. Column labeled "Before" shows the per country average yearly expenses of the class. Int. Ref. Pricing stands for International Reference Pricing.

Table 5.4: *Counterfactual Profits Changes on All Drugs*

	Canada				US				
		Int. Ref. Pricing				Int. Ref. Pricing			
ATC4	Before	Δ (%) *(N=1)*	Δ (%) *(N=6)*	Δ (%) *Comparison*	Before	Δ (%) *(N=1)*	Δ (%) *(N=6)*	Δ (%) *Comparison*	Δ (%) *Bargaining*
A10H0	33	1.8	1.8	1.4	4633	-0.0	-0.0	-1.7	-28.7
C2A2	783	0.0	0.0	0.0	6195	0.0	0.0	0.0	-28.4
C7A0	1505	2.3	2.3	1.8	61310	-0.0	-0.2	-2.0	-17.9
C8A0	8385	14.6	12.2	4.0	141424	-1.1	-5.2	-18.0	-65.6
C9A0	4815	53.1	40.7	32.4	20654	-4.7	-14.2	-31.5	-38.8
L1B0	12479	144.5	110.0	43.6	243432	-24.7	-36.2	-59.0	-45.7
L1X9	16275	5.9	3.5	-39.7	121461	-1.0	-2.1	-15.5	-25.3
L4X0	46707	53.6	25.6	26.3	193670	-9.4	-24.0	-23.2	-44.4
M1A1	375	54.4	49.3	42.7	3640	-2.4	-6.1	-14.5	-8.9
N1A2	17924	6.7	6.3	5.2	212219	-0.1	-0.3	-4.5	-8.4
N1B1	4954	3.5	3.3	0.9	36128	-0.0	-0.1	-1.4	-27.5
N3A0	2857	20.2	18.3	14.5	171438	-0.2	-1.0	-6.1	-16.6
N5A1	44548	123.8	80.5	35.1	678053	-11.4	-27.4	-53.2	-57.8
N5A9	1101	0.3	0.3	0.3	10707	-0.0	-0.1	-0.2	-1.2
N5B3	0				1827	-1.5	-1.5	-92.2	-28.3
N6A4	3221	30.3	26.8	20.6	93089	-1.1	-5.3	-15.8	-43.3
N6A9	550	2.6	2.5	2.2	23932	-0.1	-0.3	-2.4	-7.5
Total	166512	63.75	40.86	18.66	2023809	-7.98	-16.86	-31.61	-41.22

Note: Profits are average yearly in 1000 US$ (from the period 2002-2013). Δ stands for the change in expenses between after and before in percentage of initial expenses. Column labeled "Before" shows the per country average yearly profits of the class. Int. Ref. Pricing stands for International Reference Pricing.

Table 5.5: *Counterfactual World Profits Changes on All Drugs*

		Int. Ref. Pricing			
		(N=1)	*(N=6)*	*Comparison*	*Bargaining*
ATC4	Before	Δ (%)	Δ (%)	Δ (%)	Δ (%)
A10H0	4829	0.0	0.1	-1.6	-27.5
C2A2	10895	0.0	0.0	0.0	-16.2
C7A0	70338	0.0	0.1	-1.7	-15.6
C8A0	191736	-0.2	-0.6	-13.1	-48.4
C9A0	49546	3.2	17.8	-10.0	-16.2
L1B0	318308	-13.2	-1.8	-43.4	-35.0
L1X9	219110	-0.1	0.4	-11.5	-14.0
L4X0	473909	1.4	5.3	-6.9	-18.1
M1A1	5891	2.0	15.1	-6.3	-5.5
N1A2	319764	0.3	1.9	-2.7	-5.6
N1B1	65850	0.3	1.5	-0.7	-15.1
N3A0	188578	0.1	0.7	-5.3	-15.1
N5A1	945339	-2.4	3.1	-36.5	-41.5
N5A9	17315	0.0	0.0	-0.1	-0.7
N5B3	1827	-0.0	7.7	-91.0	-28.3
N6A4	112414	-0.1	0.2	-12.5	-35.9
N6A9	27234	0.0	0.1	-2.0	-6.6
Total	3022881	-1.83	2.21	-20.13	-27.59

Note: Profits are average yearly in 1000 US$ (from the period 2002-2013) for the US and the 6 reference countries using Canada as representative countries whether one or six of these are used as reference. Δ stands for the change in expenses between after and before in percentage of initial expenses. Int. Ref. Pricing stands for International Reference Pricing.

6 Conclusion

This paper addresses the important question of valuating the impact of international reference pricing of drugs in the US, taking into account the effect on referenced countries. To do this ex ante evaluation we develop a new structural model and propose a way to define the ex post equilibrium prices that such international externality would create across multiple countries. We employ detailed quantity and price data from IMS Health in our analysis to estimate a random coefficients logit demand model with a structural quality metric for each drug. Under the assumption that prices are set according to Nash bargaining between the country and firm (Horn and Wolinsky, 1988; Crawford and Yurukoglu, 2012; Grennan, 2013; Gowrisankaran et al., 2015) in a regulated price country such as Canada, we are able to separately identify costs and bargaining parameters. Since Nash bargaining involves maximizing the weighted log-sum of both parties' transaction utility, we can interpret the bargaining parameters as the degree to which

countries' policymakers choose to trade off between firm profits and immediate consumer welfare. We then perform counterfactual simulations of a most favored nation policy in the US involving international reference pricing constraints from other markets.

In the main specification, an international reference pricing policy where the price in the US cannot be higher than in Canada amounts to having Canadian prices as price ceilings for the same drugs sold in the US when firms negotiate prices with the regulator in Canada.

We find that such policy would decrease prices slightly in the US but increase them dramatically in Canada because firms will internalize the across-country restrictions involved by the US reference pricing. We find that expenses on pharmaceuticals would increase considerably in Canada but not change significantly in the US. When comparing margins of on-patent drugs present in Canada and the US, we find that while the distribution of margins differences between the US and Canada is currently skewed towards higher margins in the US, the international reference pricing policy would skew this difference towards higher margins in Canada, while prices would be close because the US would not pay over Canada for its higher marginal costs. The effects on profit and welfare show that profits of firms would increase significantly in Canada while consumer welfare would decrease, and the effects in the US remain small. Then, considering that the policy would refer to an average price of multiple countries, we show how to simulate such equilibrium and find that referring to multiple countries attenuates the strong price inflation effect of the international reference pricing policy and allows a larger price decrease in the US. However, the effect remains far from the one that one would obtain either with a required comparison clause although it is subject to commitment issues or from the one obtained directly with the US bargaining directly for prices taking account of the US demand shape only. While this research has implications for policy designs that would implement international reference pricing, it also has possible application in other contexts like the European one where external referencing is widely used or in contexts where parallel trade of drugs implicitly creates similar externality effects across markets. Allows parallel imports of on patent drugs in the US from other countries is another policy that could be modelled using the framework developed here. However, we leave for future research the extension of the effects of such policies in dynamic contexts, taking into account entry, delays as in Maini and Pammoli (2017), or even longer term effects on innovation.

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7 Appendix

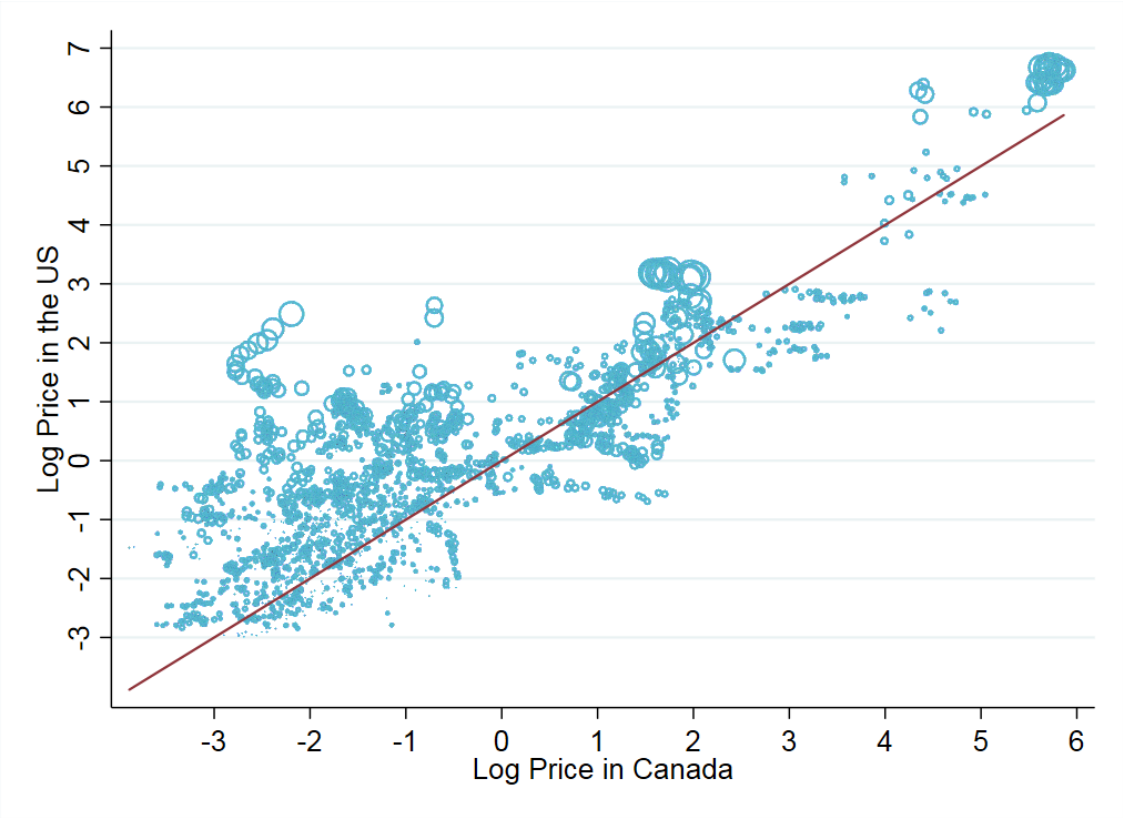
7.1 Descriptive Statistics

Table 7.1: *Average Prices in the US and Canada*

		All		Patented		Branded Off		Generic	
ATC4		CA	US	CA	US	CA	US	CA	US
A10H0	SULPHONYLUREA A-DIABS	0.05	0.35	0.64	1.04	0.35	0.79	0.05	0.20
C2A2	ANTIHYPER.PL MAINLY PERI	0.67	1.38	55.32	12.43	4.03	2.24	0.15	1.05
C7A0	B-BLOCKING AGENTS,PLAIN	0.19	1.14	0.32	6.91	1.41	1.49	0.10	0.45
C8A0	CALCIUM ANTAGONIST PLAIN	0.89	2.99	1.25	2.30	0.78	17.56	0.50	1.38
C9A0	ACE INHIBITORS PLAIN	0.57	0.60	0.66	1.67	0.54	1.51	0.31	0.33
L1B0	ANTIMETABOLITES	17.25	113.27	19.64	333.05	12.74	125.50	10.42	18.16
L1X9	ALL OTH. ANTINEOPLASTICS	21.49	130.27	420.67	734.94	0.94		0.89	14.23
L4X0	OTHER IMMUNOSUPPRESSANTS	2.95	25.87	2.97	27.02	2.66	9.57	2.87	38.32
M1A1	ANTIRHEUMATICS NON-S PLN	0.20	0.26	0.67	3.67	0.50	0.91	0.13	0.21
N1A2	INJECT GEN ANAESTHETICS	5.29	7.68	11.55	74.26	6.52	15.68	4.51	4.61
N1B1	ANAESTH LOCAL MEDIC INJ	4.35	4.30	11.10	15.77	4.52	6.00	3.15	2.83
N3A0	ANTI-EPILEPTICS	0.26	1.58	1.37	4.28	0.19	4.70	0.20	0.83
N5A1	ATYPICAL ANTIPSYCHOTICS	1.67	8.59	1.85	10.69	3.11	9.73	0.40	3.17
N5A9	CONVNTL ANTIPSYCHOTICS	0.29	1.54	1.98	2.36	0.25	14.27	0.14	1.11
N5B3	BARBITURATE PLAIN	0.14	0.56	2.08	26.51			0.11	0.29
N6A4	SSRI ANTIDEPRESSANTS	0.47	1.65	1.33	3.61	1.43	4.17	0.30	0.47
N6A9	ANTIDEPRESSANTS ALL OTH	0.21	0.71	0.63	2.83	0.61	3.43	0.15	0.33

Note: Average price by ATC-4, country, in US$ per std. unit.

Figure 7.1: *Comparisons of Prices of Generic Drugs present in both the US and Canada*



Note: Circle sizes are proportional to the sales value of this drug in the US.

7.2 Market Size Approximation

7.2.1 Method

We use Huang and Rojas (2013, 2014) to calibrate the potential market size using a simpler logit demand model. With a logit specification, we have:

$$\ln q_{jt} - \ln q_{0mt} = \alpha_{m(j)} \ln p_{jt} + \beta_{m(j)} g_j + \lambda_{m(j)} x_{jt} + \phi_j + \mu_{m(j)t} + \xi_{jt}$$

with $M_{mt} = q_{0t} + \sum_{j=1}^{J_m} q_{jt}$.

As q_{0mt} or M_{mt} are not observed, we can use the difference across inside goods to identify some of the parameters of the model:

$$\ln q_{jt} - \ln q_{j't} = \alpha_{m(j)} \left(\ln p_{jt} - \ln p_{j't} \right) + \beta_{m(j)} \left(g_j - g_{j'} \right) + \left(\phi_j - \phi_{j'} \right) + \left(\xi_{jt} - \xi_{j't} \right)$$

which does not depend on unobserved q_{0mt} or M_{mt} in order to identify α_m and β_m that are denoted $\hat{\alpha}_m$, $\hat{\beta}_m$ from these last specifications. For a given M_{mt} we have

$$\ln q_{jt} - \ln \left(M_{mt} - \sum\nolimits_{j=1}^{J_m} q_{jt} \right) = \alpha_m \ln p_{jt} + \beta_m g_j + \lambda_m x_{jt} + \phi_j + \mu_{mt} + \xi_{jt}$$

whose estimation with two stage least squares using the same instruments as with our BLP demand model leads to the estimates $\hat{\alpha}_m \left(M_{mt} \right)$, $\hat{\beta}_m \left(M_{mt} \right)$, $\hat{\lambda}_m \left(M_{mt} \right)$.

Then, we look for M_{mt} that solves the following minimization problem:

$$\min_{M_{mt} \geq \sum_{j=1}^{J_m} q_{jt}} \sum\nolimits_{t=1}^{T} \left(\hat{\alpha}_m \left(M_{mt} \right) - \hat{\alpha}_m \right)^2 + \left(\hat{\beta}_m \left(M_t \right) - \hat{\beta}_m \right)^2 + \left(\hat{\lambda}_m \left(M_t \right) - \hat{\lambda}_m \right)^2$$

7.2.2 Outside Good Market Shares Estimates

Table 7.2: *Outside Good Market Share Estimates by country and ATC-4*

		s_{0mt}	
ATC4		US	Canada
A10H0	SULPHONYLUREA A-DIABS	0.08	0.19
C2A2	ANTIHYPER.PL MAINLY PERI	0.14	0.19
C7A0	B-BLOCKING AGENTS,PLAIN	0.15	0.25
C8A0	CALCIUM ANTAGONIST PLAIN	0.13	0.21
C9A0	ACE INHIBITORS PLAIN	0.14	0.22
L1B0	ANTIMETABOLITES	0.13	0.19
L1X9	ALL OTH. ANTINEOPLASTICS	0.13	0.20
L4X0	OTHER IMMUNOSUPPRESSANTS	0.14	0.20
M1A1	ANTIRHEUMATICS NON-S PLN	0.14	0.21
N1A2	INJECT GEN ANAESTHETICS	0.14	0.20
N1B1	ANAESTH LOCAL MEDIC INJ	0.15	0.22
N3A0	ANTI-EPILEPTICS	0.14	0.20
N5A1	ATYPICAL ANTIPSYCHOTICS	0.13	0.19
N5A9	CONVNTL ANTIPSYCHOTICS	0.15	0.24
N5B3	BARBITURATE PLAIN	0.10	0.20
N6A4	SSRI ANTIDEPRESSANTS	0.16	0.22
N6A9	ANTIDEPRESSANTS ALL OTH	0.15	0.23

Note: Estimated outside good market shares obtained from the market size estimates by ATC-4, country and quarter. This Table presents average across quarters.

7.3 Demand Elasticities by ATC4

Average Price Elasticities for Canada and US for Branded or Generic drugs and by ATC4 class

		US		Canada	
ATC4 Class		Own	Cross	Own	Cross
A10H0	Branded	-1.4942911	0.18870959	-1.0860793	0.19736979
	Generic	-1.3159676	0.21979924	-0.9546113	0.22014856
A2B1	Branded	-1.5152315	0.21517432	-1.0848269	0.24501748
	Generic	-1.2444818	0.24469155	-0.8780188	0.25223733
B1B1	Branded	-1.5426189	0.24658761	-1.2884390	0.32522780
	Generic	-1.1369432	0.27678549	-0.6769721	0.42358261
B2A1	Branded	-1.4542279	0.56864347	NA	NA
	Generic	-0.5724812	0.59057725	NA	NA

B2G0	Branded	-1.1641988	0.52388993	NA	NA
	Generic	-0.8945154	0.61746712	NA	NA
B3A1	Branded	-1.5636435	0.32726816	NA	NA
	Generic	-1.1772620	0.37152563	NA	NA
B3A2	Branded	-1.5302343	0.05639156	NA	NA
	Generic	-1.5157631	0.06251615	NA	NA
B3X0	Branded	-1.5716252	0.19721732	NA	NA
	Generic	-1.1760446	0.27887549	-0.5176230	0.50505314
C10A2	Branded	-1.3109951	0.32864992	-1.1165662	0.21602872
	Generic	-1.1110397	0.34643945	-0.8862687	0.24659964
C2A1	Branded	-1.5434303	0.21773279	-1.1343419	0.36980288
	Generic	-1.2727449	0.23311667	-0.7496918	0.40283322
C2A2	Branded	-1.5430697	0.19596512	-1.0556571	0.12928930
	Generic	-1.2609796	0.23094543	-1.0028312	0.16062615
C7A0	Branded	-1.5225954	0.08140770	-1.1544918	0.07573027
	Generic	-1.4758567	0.08918033	-1.1348824	0.08268607
C7B1	Branded	-1.5515267	0.16736302	NA	NA
	Generic	-1.2397906	0.19203998	NA	NA
C8A0	Branded	-1.5201152	0.10406011	-1.1281688	0.13412558
	Generic	-1.4061916	0.11911454	-1.1350842	0.13684071
C9A0	Branded	-1.5415338	0.09380079	-1.1423198	0.08662940
	Generic	-1.4300000	0.10934890	-1.1758407	0.09214362
L1A0	Branded	-1.5127775	0.08883271	NA	NA
	Generic	-1.4102918	0.09468077	NA	NA
L1B0	Branded	-1.5120779	0.09288873	-1.0654421	0.09200356
	Generic	-1.4334406	0.09812485	-1.0789801	0.09125910
L1C0	Branded	-1.4905145	0.11252435	NA	NA
	Generic	-1.4135952	0.11792859	NA	NA
L1X9	Branded	-1.5446695	0.11363301	-0.9601175	0.21334842
	Generic	-1.1745444	0.12519897	-0.6154447	0.23554148

L2A2	Branded	-1.4552138	0.62749022	NA	NA
	Generic	-0.2889246	0.68852517	NA	NA
L4X0	Branded	-1.4539215	0.11676248	-1.0398490	0.17095603
	Generic	-1.4454776	0.11814214	-1.2217461	0.17110540
M1A1	Branded	-1.5558699	0.09806386	-1.1403284	0.10809910
	Generic	-1.4472668	0.10899561	-1.0905096	0.11884356
M1C0	Branded	-1.5468360	0.15436655	NA	NA
	Generic	-1.0971664	0.16881815	NA	NA
N1A2	Branded	-1.5381796	0.09583931	-1.1365013	0.10573899
	Generic	-1.4145795	0.10393228	-1.0929991	0.11179181
N1B1	Branded	-1.4884714	0.15268970	-1.1469470	0.14978078
	Generic	-1.3510902	0.16566433	-1.0139503	0.15489291
N1B3	Branded	-1.5225329	0.28592607	-0.5687945	0.32964770
	Generic	-1.1182851	0.32033762	-1.1492827	0.35418571
N2A0	Branded	-1.5318372	0.09733111	-1.2028092	0.08586507
	Generic	-1.4555158	0.10729789	-1.1593344	0.08859004
N2B0	Branded	-1.5566200	0.08849977	-1.1435220	0.11517178
	Generic	-1.4559112	0.10354999	-1.0495434	0.12870232
N3A0	Branded	-1.5410147	0.07146262	-1.1438252	0.06380140
	Generic	-1.4682858	0.07298318	-1.1688601	0.06889266
N5A1	Branded	-1.4325883	0.15923412	-1.0438251	0.14885769
	Generic	-1.3348840	0.14654554	-1.1024702	0.13396985
N5A9	Branded	-1.5689278	0.10878572	-1.1422646	0.06935789
	Generic	-1.4134348	0.12795686	-1.1710016	0.08122847
N5B3	Branded	-1.5656956	0.48183507	-1.0560144	0.45645669
	Generic	-0.7831270	0.48614769	-0.1291302	0.57427448
N5C0	Branded	-1.5753682	0.11862044	-1.1388552	0.10165958
	Generic	-1.4196950	0.14993512	-1.1690914	0.10665044
N6A4	Branded	-1.3960100	0.18112970	-1.1195133	0.13900737
	Generic	-1.3594402	0.19680851	-1.0695640	0.15707022

N6A9	Branded	-1.5419200	0.07511176	-1.1733263	0.06326497
	Generic	-1.4769645	0.08648495	-1.1793534	0.06730979
N6B0	Branded	-1.4731393	0.13266753	NA	NA
	Generic	-1.3654408	0.13928647	NA	NA

Note: Average price elasticities across all products of each ATC-4 market over all quarters. Some ATC-4 markets may not be available in both countries.

7.4 Supply sides estimates

Table 7.4: *Margins Estimates by ATC-4*

Margins		Canada				US		
ATC4	Label	All	On Patent	Branded Off Patent	Generics	All	On Patent	Branded Off Patent
A10H0	SULPHONYLUREA A-DIABS	1.10	1.38	2.93		41.66	73.84	76.66
C2A2	ANTIHYPER.PL MAINLY PERI	24.59	74.94	48.90		17.11	65.40	3.50
C7A0	B-BLOCKING AGENTS,PLAIN	7.47	6.08	21.26	1.99	45.39	65.06	67.63
C8A0	CALCIUM ANTAGONIST PLAIN	18.20	48.62	6.34	1.63	58.38	95.33	64.21
C9A0	ACE INHIBITORS PLAIN	48.70	58.35	40.50	11.71	38.58	46.33	69.26
L1B0	ANTIMETABOLITES	5.29	5.14	10.38	5.30	59.45	66.81	65.15
L1X9	ALL OTH. ANTINEOPLASTICS	8.81	9.56		1.40	60.02	66.07	
L4X0	OTHER IMMUNOSUPPRESSANTS	8.47	16.67	3.48	0.21	40.41	69.46	73.71
M1A1	ANTIRHEUMATICS NON-S PLN	15.40	30.38	42.56	6.33	13.88	44.37	50.03
N1A2	INJECT GEN ANAESTHETICS	47.57	11.22	71.35	51.82	35.39	65.76	77.59
N1B1	ANAESTH LOCAL MEDIC INJ	71.46	59.65	92.85	52.91	31.47	70.67	27.05
N3A0	ANTI-EPILEPTICS	3.92	7.30	4.86		39.12	67.38	65.87
N5A1	ATYPICAL ANTIPSYCHOTICS	11.30	4.73	81.31		69.17	77.21	28.45
N5A9	CONVNTL ANTIPSYCHOTICS	7.14	83.93			20.77	33.60	65.30
N5B3	BARBITURATE PLAIN					31.73	63.91	
N6A4	SSRI ANTIDEPRESSANTS	14.25	11.58	12.04	26.21	65.09	80.10	70.75
N6A9	ANTIDEPRESSANTS ALL OTH	6.18	36.61	3.58	2.90	42.91	68.63	72.63

Note: Average margins in percentage of US average price by ATC-4 across all quarters. Average across drugs within category is weighted by market share. For generics in the US we impose price equal to marginal costs and do not estimate margins but they are taken into account in the average margin for all drugs in the US.

Table 7.5: *Estimates of ρ_{jm} by ATC-4*

ATC4		On Patent	Branded Off	Generic
A10H0	SULPHONYLUREA A-DIABS	0.91	0.51	0.00
C2A2	ANTIHYPER.PL MAINLY PERI	0.66	0.48	0.00
C7A0	B-BLOCKING AGENTS,PLAIN	0.87	0.80	0.04
C8A0	CALCIUM ANTAGONIST PLAIN	0.80	0.53	0.10
C9A0	ACE INHIBITORS PLAIN	0.56	0.50	0.57
L1B0	ANTIMETABOLITES	0.34	1.00	0.32
L1X9	ALL OTH. ANTINEOPLASTICS	0.41	0.00	0.23
L4X0	OTHER IMMUNOSUPPRESSANTS	0.80	0.71	0.15
M1A1	ANTIRHEUMATICS NON-S PLN	0.34	0.48	0.13
N1A2	INJECT GEN ANAESTHETICS	0.58	0.87	0.64
N1B1	ANAESTH LOCAL MEDIC INJ	0.89	1.00	0.57
N3A0	ANTI-EPILEPTICS	0.71	0.38	0.00
N5A1	ATYPICAL ANTIPSYCHOTICS	0.55	0.82	0.00
N5A9	CONVNTL ANTIPSYCHOTICS	0.89	0.00	0.00
N5B3	BARBITURATE PLAIN	0.00		0.00
N6A4	SSRI ANTIDEPRESSANTS	0.76	0.79	0.34
N6A9	ANTIDEPRESSANTS ALL OTH	0.72	0.36	0.04

Table 7.6: *Marginal costs Estimates by ATC-4*

Margins		Canada				US			
ATC4	Label	All	On Patent	Branded Off Patent	Generics	All	On Patent	Branded Off Patent	Generics
A10H0	SULPHONYLUREA A-DIABS	0.05	0.11	0.19	0.05	0.21	0.27	0.18	0.20
C2A2	ANTIHYPER.PL MAINLY PERI	0.31	13.26	2.06	0.15	1.14	4.30	0.81	1.05
C7A0	B-BLOCKING AGENTS,PLAIN	0.10	0.07	0.34	0.09	0.63	2.42	0.48	0.45
C8A0	CALCIUM ANTAGONIST PLAIN	0.29	0.08	0.43	0.46	1.25	0.11	6.29	1.38
C9A0	ACE INHIBITORS PLAIN	0.25	0.28	0.29	0.16	0.37	0.51	0.46	0.33
L1B0	ANTIMETABOLITES	10.77	12.23	1.18	7.43	45.93	110.56	43.74	18.16
L1X9	ALL OTH. ANTINEOPLASTICS	9.10	171.62	0.94	0.59	52.09	249.36	0.00	14.23
L4X0	OTHER IMMUNOSUPPRESSANTS	0.59	0.47	0.82	2.41	15.42	8.25	2.52	38.32
M1A1	ANTIRHEUMATICS NON-S PLN	0.15	0.47	0.29	0.11	0.23	1.31	0.30	0.21
N1A2	INJECT GEN ANAESTHETICS	1.35	5.82	0.55	1.41	4.97	25.43	3.51	4.61
N1B1	ANAESTH LOCAL MEDIC INJ	1.01	2.06	0.32	1.07	2.95	4.63	1.90	2.83
N3A0	ANTI-EPILEPTICS	0.20	0.44	0.13	0.20	0.96	1.40	1.60	0.83
N5A1	ATYPICAL ANTIPSYCHOTICS	0.63	0.86	0.58	0.40	2.65	2.44	2.79	3.17
N5A9	CONVNTL ANTIPSYCHOTICS	0.16	0.32	0.25	0.14	1.22	0.84	4.95	1.11
N5B3	BARBITURATE PLAIN	0.14	2.08		0.11	0.39	9.57		0.29
N6A4	SSRI ANTIDEPRESSANTS	0.21	0.28	0.40	0.20	0.58	0.72	1.22	0.47
N6A9	ANTIDEPRESSANTS ALL OTH	0.17	0.21	0.41	0.14	0.41	0.89	0.94	0.33

Note: Average marginal costs by ATC-4 across all quarters. Average across drugs within category is weighted by market share. For generics in the US we impose price equal to marginal costs and do not estimate margins but they are taken into account in the average margin for all drugs in the US.

7.5 Theoretical Results

This section shows that under "regularity" conditions of the profit function and when the same drugs are present in the referencing and referenced country, a single country international reference pricing policy can only increase price in the referenced country and decrease it in the referencing country. We start by showing it when we have a monopoly drug in each country, then when we have a duopoly.

7.5.1 Monopoly case

Let's start with a monopoly firm in each country A and B. Consider one firm producing a product, at marginal costs c. Denote $D_A(p_A)$ and $D_B(p_B)$ the demands in countries A and B, respectively, when their prices are p_A and p_B. We assume that each profit function $\Pi_A(p_A) \equiv (p_A - c) D_A(p_A)$ and $\Pi_B(p_B) \equiv (p_B - c) D_B(p_B)$ is strictly concave in price and have a finite maximum above marginal cost.

Under regulation, we suppose that a governmental agency negotiates price by engaging in Nash bargaining with the firm. The government's objective function takes the general form $W(p_B)$ in country B, where $W(.)$ is decreasing over $[c, +\infty)$. For instance, $W(p_B)$ could be consumer surplus, social welfare or coverage.

Thus, the unregulated price in country A solves

$$p_A^* = \underset{c \leq p_A}{\arg\max} \Pi_A(p_A)$$

and the price in country B under regulation solves the following maximization program:

$$p_B^* = \underset{p_B \geq c}{\arg\max} \Pi_B(p_B)^{1-\rho} \Delta W(p_B)^{\rho}$$

where $\Delta W(p_B) \equiv W(p_B) - W(\infty)$ is decreasing in p_B and $\rho \in (0, 1]$ captures the bargaining power of the governmental agency.

Now with international reference pricing imposing that the firm can sell in country A only if $p_A \leq p_B$, the new price equilibrium (p_A^{**}, p_B^{**}) simultaneously solves:

$$\begin{cases} p_A^{**} = \tilde{p}_A(p_B^{**}) \equiv \underset{c \leq p_A \leq p_B^{**}}{\arg\max} \Pi_A(p_A) \\ p_B^{**} = \underset{p_B \geq c}{\arg\max} \left[\Pi_A(\tilde{p}_A(p_B)) + \Pi_B(p_B) - \Pi_A(p_A^*)\right]^{1-\rho} \Delta W(p_B)^{\rho} \end{cases}$$

where $\Pi_A(\tilde{p}_A(p_B)) + \Pi_B(p_B)$ is the firm profit in A and B if selling if both countries and $\Pi_A(p_A^*)$ is the firm profit in A only if disagreeing with B.

Proposition The international reference pricing policy implies that the price in country A decreases and the price in country B increases:

$$p_A^{**} \leq p_A^* \quad \text{and} \quad p_B^{**} \geq p_B^*$$

Proof *Let's start with proving that* $p_A^{**} \leq p_A^*$*:*

From its definition, $p_A^{**} \equiv \tilde{p}_A(p_B^{**}) = p_A^*$ if $p_A^* \leq p_B^{**}$. If $p_A^* > p_B^{**}$, then $p_A^{**} \equiv \tilde{p}_A(p_B^{**}) \leq p_B^{**}$ because $\tilde{p}_A(p) \leq p$ for all p and thus $p_A^{**} < p_A^*$. This proves that in all cases $p_A^{**} \leq p_A^*$.

Let's prove now that $p_B^{**} \geq p_B^*$*:*

Let's define

$$\Delta\Pi_A(p_A^*, p_B)) \equiv \Pi_A(\tilde{p}_A(p_B)) - \Pi_A(p_A^*)$$

$\Delta\Pi_A\left(p_A^*, p_B\right))$ is negative increasing in p_B and equal to zero when $p_B \geq p_A^*$:

It is negative because $p_A^* = \arg\max_{p_A \geq c} \Pi_A\left(p_A\right)$ and thus $\Pi_A\left(\tilde{p}_A(p_B)\right) \leq \Pi_A\left(p_A^*\right)$. By concavity of $\Pi_A\left(.\right)$, it is increasing on $[0, p_A^*[$, $\tilde{p}_A(p_B)$ is also weakly increasing in p_B, thus $\Pi_A\left(\tilde{p}_A(p_B)\right)$ is increasing in p_B because $\tilde{p}_A(p_B) \leq \tilde{p}_A(p_A^*) \leq p_A^*$.

Then, using $p_B^{**} = \arg\max_{p_B \geq c} \left[\Pi_B\left(p_B\right) + \Delta\Pi_A\left(p_A^*, p_B\right)\right] \Delta W\left(p_B\right)^{\frac{\rho}{1-\rho}}$ and $p_B^* = \arg\max_{p_B \geq c} \Pi_B\left(p_B\right) \Delta W\left(p_B\right)^{\frac{\rho}{1-\rho}}$, we have

$$
\begin{aligned}
& \Pi_B\left(p_B^{**}\right) \Delta W\left(p_B^{**}\right)^{\frac{\rho}{1-\rho}} + \Delta\Pi_A\left(p_A^*, p_B^{**}\right) \Delta W\left(p_B^{**}\right)^{\frac{\rho}{1-\rho}} \\
= \; & \left[\Pi_B\left(p_B^{**}\right) + \Delta\Pi_A\left(p_A^*, p_B^{**}\right)\right] \Delta W\left(p_B^{**}\right)^{\frac{\rho}{1-\rho}} \\
\geq \; & \left[\Pi_B\left(p_B^{*}\right) + \Delta\Pi_A\left(p_A^*, p_B^{*}\right)\right] \Delta W\left(p_B^{*}\right)^{\frac{\rho}{1-\rho}} \text{ because of the definition of } p_B^{**} \\
= \; & \Pi_B\left(p_B^{*}\right) \Delta W\left(p_B^{*}\right)^{\frac{\rho}{1-\rho}} + \Delta\Pi_A\left(p_A^*, p_B^{*}\right) \Delta W\left(p_B^{*}\right)^{\frac{\rho}{1-\rho}} \\
\geq \; & \Pi_B\left(p_B^{**}\right) \Delta W\left(p_B^{**}\right)^{\frac{\rho}{1-\rho}} + \Delta\Pi_A\left(p_A^*, p_B^{*}\right) \Delta W\left(p_B^{*}\right)^{\frac{\rho}{1-\rho}} \text{ because of the definition of } p_B^{*}
\end{aligned}
$$

Thus

$$\Delta\Pi_A\left(p_A^*, p_B^{**}\right) \Delta W\left(p_B^{**}\right)^{\frac{\rho}{1-\rho}} \geq \Delta\Pi_A\left(p_A^*, p_B^{*}\right) \Delta W\left(p_B^{*}\right)^{\frac{\rho}{1-\rho}}$$

If $p_B^* \geq p_B^{**}$ then $\Delta\Pi_A\left(p_A^*, p_B^*\right)) \Delta W\left(p_B^*\right)^{\frac{\rho}{1-\rho}} \geq \Delta\Pi_A\left(p_A^*, p_B^*\right)) \Delta W\left(p_B^{**}\right)^{\frac{\rho}{1-\rho}}$ because $\Delta\Pi_A\left(p_A^*, p_B^*\right)) \leq 0$ and $\Delta W\left(.\right)$ is positive decreasing. Using the above inequality, it implies

$$\Delta\Pi_A\left(p_A^*, p_B^{**}\right) \geq \Delta\Pi_A\left(p_A^*, p_B^{*}\right)$$

and thus $p_B^{**} \geq p_B^*$ because $\Delta\Pi_A\left(p_A^*, p_B\right)$ is increasing in p_B, which contradicts $p_B^* \geq p_B^{**}$ implying that it must be that $p_B^{**} \geq p_B^*$.

7.5.2 Duopoly case

Consider two firms competing against each other and producing two differentiated products, 1 and 2, at marginal costs c, respectively. Denote $D_{1c}\left(p_{1c}, p_{2c}\right)$ and $D_{2c}\left(p_{1c}, p_{2c}\right)$ as demands for products 1 and 2 in country c, respectively, when their prices are given by p_{1c} and p_{2c}. We assume that each firm i's profit function $\Pi_{ic} \equiv \left(p_{ic} - c\right) D_{ic}\left(p_{ic}, p_{-ic}\right)$ is strictly concave in its own price, weakly increasing in the rival's price, and that its best-response price is increasing in its rival's price (i.e., prices are strategic complements). We suppose further that a Nash equilibrium (p_{1c}^*, p_{2c}^*) to the Bertrand game exists and is unique.

Under regulation, we suppose that a governmental agency negotiates prices by engaging in simultaneous Nash bargaining with both firms. We assume that the governmental agency's

objective function of country B takes the general form $W(p_{1B}, p_{2B})$, where $W(.,.)$ is decreasing over $[c, +\infty) \times [c, +\infty)$. For instance, $W(p_{1B}, p_{2B})$ could be consumer surplus, social welfare or coverage.

The prices that arise in country A solve the Bertrand-Nash equilibrium

$$\begin{cases} p_{1A}^* = \underset{p_{1A} \geq c}{\arg\max} \Pi_{1A}(p_{1A}, p_{2A}^*) \\ p_{2A}^* = \underset{p_{2A} \geq c}{\arg\max} \Pi_{2A}(p_{1A}^*, p_{2A}) \end{cases}$$

and in country B, the regulation solves the following system of maximization programs:

$$\begin{cases} p_{1B}^* = \underset{p_{1B} \geq c}{\arg\max} \Pi_{1B}(p_{1B}, p_{2B}^*)^{1-\rho_1} \Delta W_1(p_{1B}, p_{2B}^*)^{\rho_1} \\ p_{2B}^* = \underset{p_{2B} \geq c}{\arg\max} \Pi_{2B}(p_{1B}^*, p_{2B})^{1-\rho_2} \Delta W_2(p_{1B}^*, p_{2B})^{\rho_2} \end{cases} \tag{7.1}$$

where $\Delta W_1(p_{1B}, p_{2B}^*) \equiv W(p_{1B}, p_{2B}^*) - W(\infty, p_{2B}^*)$, $\Delta W_2(p_{1B}^*, p_{2B}) \equiv W(p_{1B}^*, p_{2B}) - W(p_{1B}^*, \infty)$, and $\rho_1, \rho_2 \in (0, 1]$ capture the bargaining power of the governmental agency in its negotiation with firms 1 and 2, respectively. We assume that the pair (p_{1B}^*, p_{2B}^*) solving the system exists and is unique.

We now consider the international reference pricing equilibrium that satisfies

$$\begin{cases} p_{1A}^{**} = \tilde{p}_{1A}(p_{1B}^{**}, p_{2A}^{**}) \equiv \underset{p_{1A} \leq p_{1B}^{**}}{\arg\max} \Pi_{1A}(p_{1A}, p_{2A}^{**}) \\ p_{2A}^{**} = \tilde{p}_{2A}(p_{1A}^{**}, p_{2B}^{**}) \equiv \underset{p_{2A} \leq p_{2B}^{**}}{\arg\max} \Pi_{2A}(p_{1A}^{**}, p_{2A}) \\ p_{1B}^{**} = \underset{p_{1B} \geq c}{\arg\max} \left[\Pi_{1A}(\tilde{p}_{1A}(p_{1B}, p_{2A}^{**}), p_{2A}^{**}) + \Pi_{1B}(p_{1B}, p_{2B}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})\right]^{1-\rho_1} \Delta W_1(p_{1B}, p_{2B}^{**})^{\rho_1} \\ p_{2B}^{**} = \underset{p_{2B} \geq c}{\arg\max} \left[\Pi_{2A}(p_{1A}^{**}, \tilde{p}_{2A}(p_{1A}^{**}, p_{2B})) + \Pi_{2B}(p_{1B}^{**}, p_{2B}) - \Pi_{2A}(p_{1A}^{**}, p_{2A}^*)\right]^{1-\rho_2} \Delta W_2(p_{1B}^{**}, p_{2B})^{\rho_2} \end{cases}$$

Remark that imposing the reference pricing constraint on one product only would generate the same proposition, but for simplicity of exposition we consider the symmetric case.

Proposition The international reference pricing policy implies that the prices in country A decrease and the prices in country B increase:

$$p_{iA}^{**} \leq p_{iA}^* \quad \text{and} \quad p_{iB}^{**} \geq p_{iB}^* \quad \text{for } i = 1, 2$$

Proof *Let's start with proving that* $p_{iA}^{**} \leq p_{iA}^*$ *for* $i = 1, 2$*:*

By definition of the solution of

$$\begin{cases} p_{1A}^{*} = \tilde{p}_{1A}\left(\infty, p_{2A}^{*}\right) = \underset{p_{1A}}{\arg\max} \Pi_{1A}\left(p_{1A}, p_{2A}^{*}\right) \\ p_{2A}^{*} = \tilde{p}_{2A}\left(p_{1A}^{*}, \infty\right) = \underset{p_{2A}}{\arg\max} \Pi_{2A}\left(p_{1A}^{*}, p_{2A}\right) \end{cases}$$

and

$$\begin{cases} p_{1A}^{**} = \tilde{p}_{1A}\left(p_{1B}^{**}, p_{2A}^{**}\right) \equiv \underset{p_{1A} \leq p_{1B}^{**}}{\arg\max} \Pi_{1A}\left(p_{1A}, p_{2A}^{**}\right) \\ p_{2A}^{**} = \tilde{p}_{2A}\left(p_{1A}^{**}, p_{2B}^{**}\right) \equiv \underset{p_{2A} \leq p_{2B}^{**}}{\arg\max} \Pi_{2A}\left(p_{1A}^{**}, p_{2A}\right) \end{cases}$$

Then

$$\begin{aligned} p_{1A}^{**} &= \tilde{p}_{1A}\left(p_{1B}^{**}, p_{2A}^{**}\right) \leq \tilde{p}_{1A}\left(\infty, p_{2A}^{**}\right) \leq \tilde{p}_{1A}\left(\infty, p_{2A}^{*}\right) = p_{1A}^{*} \text{ if } p_{2A}^{**} \leq p_{2A}^{*} \\ p_{2A}^{**} &= \tilde{p}_{2A}\left(p_{1A}^{**}, p_{2B}^{**}\right) \leq \tilde{p}_{2A}\left(p_{1A}^{**}, \infty\right) \leq \tilde{p}_{2A}\left(p_{1A}^{*}, \infty\right) = p_{2A}^{*} \text{ if } p_{1A}^{**} \leq p_{1A}^{*} \end{aligned}$$

If $p_{1A}^{**} > p_{1A}^{*}$ then $p_{2A}^{**} = \tilde{p}_{2A}\left(p_{1A}^{**}, p_{2B}^{**}\right) \geq \tilde{p}_{2A}\left(p_{1A}^{*}, p_{2B}^{**}\right) = p_{2A}^{*}$ if $p_{2B}^{**} \geq p_{2A}^{*}$. Thus $p_{1A}^{**} > p_{1A}^{*}$ implies $p_{2A}^{**} > p_{2A}^{*}$ if $p_{2B}^{**} \geq p_{2A}^{*}$, but both prices increasing is not possible by definition of the unconstrained Nash equilibrium. Thus, it must be that if $p_{1A}^{**} > p_{1A}^{*}$ then $p_{2B}^{**} < p_{2A}^{*}$, but then $p_{2A}^{**} \leq p_{2B}^{**} < p_{2A}^{*}$. But we have shown that if $p_{2A}^{**} \leq p_{2A}^{*}$ then $p_{1A}^{**} \leq p_{1A}^{*}$ which proves that we must have both $p_{iA}^{**} \leq p_{iA}^{*}$ for $i = 1, 2$.

Let's prove now that $p_{iB}^{**} \geq p_{iB}^{*}$ for $i = 1, 2$:

Remark that $\tilde{p}_{1A}(p_{1B}, p_{2A})$ is weakly increasing in the second argument p_{2A} because of strategic complementarity in profit, and symmetrically for $\tilde{p}_{2A}(.,.)$.

Moreover, $\tilde{p}_{1A}(p_{1B}, p_{2A})$ is weakly increasing in the first argument p_{1B} because of the concavity of the profit function in its own price.

Moreover, $\tilde{p}_{1A}(p_{1B}, p_{2A}^{**}) \leq \tilde{p}_{1A}(p_{1B}, p_{2A}^{*})$ and $\tilde{p}_{2A}\left(p_{1A}^{**}, p_{2B}\right) \leq \tilde{p}_{2A}\left(p_{1A}^{*}, p_{2B}\right)$ since $p_{iA}^{**} \leq p_{iA}^{*}$.

Then, $\tilde{p}_{1A}(p_{1B}, p_{2A}^{*}) \leq p_{1A}^{*}$ and thus $\tilde{p}_{1A}(p_{1B}, p_{2A}^{**}) \leq p_{1A}^{*}$ which implies that

$$\Delta\Pi_{1A}\left(p_{1B}, p_{1A}^{*}, p_{2A}^{**}\right) \equiv \Pi_{1A}\left(\tilde{p}_{1A}\left(p_{1B}, p_{2A}^{**}\right), p_{2A}^{**}\right) - \Pi_{1A}\left(p_{1A}^{*}, p_{2A}^{**}\right) \leq 0$$

because the reaction function of firm 2 is increasing in the price of firm 1. Similarly $\Pi_{2A}\left(p_{1A}^{**}, \tilde{p}_{2A}\left(p_{1A}^{**}, p_{2B}\right)\right) - \Pi_{2A}\left(p_{1A}^{**}, p_{2A}^{*}\right) \leq 0$.

Moreover, $\Pi_{1A}\left(\tilde{p}_{1A}\left(p_{1B}, p_{2A}^{**}\right), p_{2A}^{**}\right) - \Pi_{1A}\left(p_{1A}^{*}, p_{2A}^{**}\right)$ is then weakly increasing in p_{1B} as well as $\Pi_{2A}\left(p_{1A}^{**}, \tilde{p}_{2A}\left(p_{1A}^{**}, p_{2B}\right)\right) - \Pi_{2A}\left(p_{1A}^{**}, p_{2A}^{*}\right)$ in p_{2B}.

$\Delta W_1(p_{1B}, p_{2B}^*) \equiv W(p_{1B}, p_{2B}^*) - W(\infty, p_{2B}^*) \geq 0$ is decreasing in p_{1B} and $\Delta W_2(p_{1B}^*, p_{2B}) \equiv W(p_{1B}^*, p_{2B}) - W(p_{1B}^*, \infty) \geq 0$ is decreasing in p_{2B}.

Define

$$\tilde{\Pi}_{1B}(p_{1B}, p_{1A}^*, p_{2A}^{**}, p_{2B}^{**}) = \Pi_{1A}(\tilde{p}_{1A}(p_{1B}, p_{2A}^{**}), p_{2A}^{**}) + \Pi_{1B}(p_{1B}, p_{2B}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})$$

and

$$\tilde{\Pi}_{2B}(p_{2B}, p_{2A}^*, p_{1A}^{**}, p_{1B}^{**}) = \Pi_{2A}(p_{1A}^{**}, \tilde{p}_{2A}(p_{1A}^{**}, p_{2B})) + \Pi_{2B}(p_{1B}^{**}, p_{2B}) - \Pi_{2A}(p_{1A}^{**}, p_{2A}^*)$$

As $\Pi_{1B}(p_{1B}, p_{2B})$ is increasing in p_{1B} for $p_{1B} \leq \bar{p}_{1B}(p_{2B})$ and increasing in p_{2B}, we have that $\tilde{\Pi}_{1B}(p_{1B}, p_{1A}^*, p_{2A}^{**}, p_{2B}^{**})$ is increasing in p_{1B} for $p_{1B} \leq \bar{p}_{1B}(p_{2B})$ and increasing in p_{2B}^{**}. Symmetrically, $\tilde{\Pi}_{2B}(p_{2B}, p_{2A}^*, p_{1A}^{**}, p_{1B}^{**})$ is increasing in p_{2B} for $p_{2B} \leq \bar{p}_{2B}(p_{1B})$ and increasing in p_{1B}^{**}.

Moreover, because of the previous inequalities, $\tilde{\Pi}_{1B}(p_{1B}, p_{1A}^*, p_{2A}^{**}, p_{2B}^{**}) \leq \Pi_{1B}(p_{1B}, p_{2B}^{**})$ and $\tilde{\Pi}_{2B}(p_{2B}, p_{2A}^*, p_{1A}^{**}, p_{1B}^{**}) \leq \Pi_{2B}(p_{1B}^{**}, p_{2B})$.

Then

$$\begin{aligned}
& [\Pi_{1A}(\tilde{p}_{1A}(p_{1B}^{**}, p_{2A}^{**}), p_{2A}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})] \Delta W_1(p_{1B}^{**}, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} + \Pi_{1B}(p_{1B}^{**}, p_{2B}^{**}) \Delta W_1(p_{1B}^{**}, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} \\
= \; & [\Pi_{1A}(\tilde{p}_{1A}(p_{1B}^{**}, p_{2A}^{**}), p_{2A}^{**}) + \Pi_{1B}(p_{1B}^{**}, p_{2B}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})] \Delta W_1(p_{1B}^{**}, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} \\
\geq \; & [\Pi_{1A}(\tilde{p}_{1A}(p_{1B}^*, p_{2A}^{**}), p_{2A}^{**}) + \Pi_{1B}(p_{1B}^*, p_{2B}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})] \Delta W_1(p_{1B}^*, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} \\
& \text{because of the definition of } p_{1B}^{**} \\
= \; & [\Pi_{1A}(\tilde{p}_{1A}(p_{1B}^*, p_{2A}^{**}), p_{2A}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})] \Delta W_1(p_{1B}^*, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} + \Pi_{1B}(p_{1B}^*, p_{2B}^{**}) \Delta W_1(p_{1B}^*, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} \\
\geq \; & [\Pi_{1A}(\tilde{p}_{1A}(p_{1B}^*, p_{2A}^{**}), p_{2A}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})] \Delta W_1(p_{1B}^*, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} + \Pi_{1B}(p_{1B}^{**}, p_{2B}^{**}) \Delta W_1(p_{1B}^{**}, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} \\
& \text{because of the definition of } p_{1B}^*
\end{aligned}$$

then, using the fact that $\Delta\Pi_{1A}(p_{1B}^{**}, p_{1A}^*, p_{2A}^{**}) = \Pi_{1A}(\tilde{p}_{1A}(p_{1B}^{**}, p_{2A}^{**}), p_{2A}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})$ and $\Delta\Pi_{1A}(p_{1B}^*, p_{1A}^*, p_{2A}^{**}) = \Pi_{1A}(\tilde{p}_{1A}(p_{1B}^*, p_{2A}^{**}), p_{2A}^{**}) - \Pi_{1A}(p_{1A}^*, p_{2A}^{**})$ the previous inequality implies that

$$\Delta\Pi_{1A}(p_{1B}^{**}, p_{1A}^*, p_{2A}^{**}) \Delta W_1(p_{1B}^{**}, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}} \geq \Delta\Pi_{1A}(p_{1B}^*, p_{1A}^*, p_{2A}^{**}) \Delta W_1(p_{1B}^*, p_{2B}^{**})^{\frac{\rho_1}{1-\rho_1}}$$

thus

$$\left(\frac{\Delta W_1(p_{1B}^{**}, p_{2B}^{**})}{\Delta W_1(p_{1B}^*, p_{2B}^{**})}\right)^{\frac{\rho_1}{1-\rho_1}} \leq \frac{\Delta\Pi_{1A}(p_{1B}^*, p_{1A}^*, p_{2A}^{**})}{\Delta\Pi_{1A}(p_{1B}^{**}, p_{1A}^*, p_{2A}^{**})}$$

because $\Delta\Pi_{1A}\left(p_{1B}^{**}, p_{1A}^{*}, p_{2A}^{**}\right) \leq 0$.

This inequality if not possible if $p_{1B}^{**} < p_{1B}^{*}$ because in such case $\frac{\Delta W_1(p_{1B}^{**}, p_{2B}^{**})}{\Delta W_1\left(p_{1B}^{*}, p_{2B}^{**}\right)} > 1$ because $\Delta W_1\left(p_{1B}, p_{2B}\right)$ is decreasing in p_{1B}, and $\frac{\Delta\Pi_{1A}(p_{1B}^{*}, p_{1A}^{*}, p_{2A}^{**})}{\Delta\Pi_{1A}\left(p_{1B}^{**}, p_{1A}^{*}, p_{2A}^{**}\right)} \leq 1$ because $\Delta\Pi_{1A}\left(p_{1B}, p_{1A}^{*}, p_{2A}^{**}\right)$ is increasing in p_{1B} but negative. This implies that necessarily $p_{1B}^{**} \geq p_{1B}^{*}$. Symmetrically $p_{2B}^{**} \geq p_{2B}^{*}$.

7.6 Additional Tables of counterfactuals

Table 7.7: *Counterfactual Expenses Changes on All Drugs when International Reference Pricing w.r.t. Six Countries*

		ρ_{jm}		Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	392	392	-0.0	11065	11065	0.0
C2A2	0.66	0.48	0.00	1468	1468	0.0	34117	34117	0.0
C7A0	0.87	0.80	0.04	3027	3041	0.5	134842	134754	-0.1
C8A0	0.80	0.53	0.10	12454	13993	12.4	240970	226362	-6.1
C9A0	0.56	0.50	0.57	8646	10722	24.0	52300	51154	-2.2
L1B0	0.34	1.00	0.32	32322	47885	48.1	408366	305663	-25.1
L1X9	0.41	0.00	0.23	28033	28508	1.7	201395	199150	-1.1
L4X0	0.80	0.71	0.15	58224	70289	20.7	478261	368499	-23.0
M1A1	0.34	0.48	0.13	1666	1701	2.1	26388	26786	1.5
N1A2	0.58	0.87	0.64	23090	23966	3.8	602738	603968	0.2
N1B1	0.89	1.00	0.57	6434	6571	2.1	114498	114618	0.1
N3A0	0.71	0.38	0.00	11284	11457	1.5	436053	435239	-0.2
N5A1	0.55	0.82	0.00	70817	106483	50.4	966348	777296	-19.6
N5A9	0.89	0.00	0.00	2584	2586	0.1	51089	51064	-0.0
N5B3	0.00		0.00	138	145	4.8	5856	6116	4.4
N6A4	0.76	0.79	0.34	6018	6842	13.7	143410	139140	-3.0
N6A9	0.72	0.36	0.04	2509	2516	0.3	54167	54150	-0.0
Total				111318	150217	34.9	2009155	1781725	-11.3

Note: Expenses are average yearly expenses in 1000 US$ (from the period 2002-2013). Δ stands for the change in expenses between after and before in percentage of initial expenses. The parameter ρ_{jm} is the one estimated from the supply model in Canada and used for counterfactual simulations.

Table 7.8: *Counterfactual Quantity Changes on All Drugs when International Reference Pricing w.r.t. Canada*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	7456	7454	-0.0	31368	31368	0.0
C2A2	0.66	0.48	0.00	2192	2192	0.0	24541	24541	0.0
C7A0	0.87	0.80	0.04	15534	15509	-0.2	117554	117564	0.0
C8A0	0.80	0.53	0.10	13914	13590	-2.3	81326	81552	0.3
C9A0	0.56	0.50	0.57	15207	14629	-3.8	86360	86913	0.6
L1B0	0.34	1.00	0.32	1946	1826	-6.2	3663	3786	3.4
L1X9	0.41	0.00	0.23	1197	1192	-0.4	1513	1515	0.2
L4X0	0.80	0.71	0.15	19670	18573	-5.6	18152	18619	2.6
M1A1	0.34	0.48	0.13	8517	8462	-0.6	101113	101191	0.1
N1A2	0.58	0.87	0.64	4337	4314	-0.5	79637	79646	0.0
N1B1	0.89	1.00	0.57	1483	1477	-0.4	26664	26666	0.0
N3A0	0.71	0.38	0.00	42539	42387	-0.4	274139	274260	0.0
N5A1	0.55	0.82	0.00	42657	39891	-6.5	112294	114402	1.9
N5A9	0.89	0.00	0.00	9071	9069	-0.0	33114	33115	0.0
N5B3	0.00		0.00	1054	1053	-0.1	10569	10572	0.0
N6A4	0.76	0.79	0.34	13482	13302	-1.3	86964	87068	0.1
N6A9	0.72	0.36	0.04	11806	11797	-0.1	74626	74632	0.0
Total				46227	44986	-2.6	995296	998506	.3

Note: Quantity are average yearly standard units (on period 2002-2013). Δ *stands for the change of quantity between after and before in percentage of initial quantity. The parameter* ρ_{jm} *is the one estimated from the supply model in Canada and used for counterfactual simulations.*

Table 7.9: *Counterfactual Quantity Changes on All Drugs when International Reference Pricing w.r.t. Six Countries*

	ρ_{jm}			Canada			US		
ATC4	*On Patent*	*Branded Off*	*Generic*	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	7456	7454	-0.0	31368	31370	0.0
C2A2	0.66	0.48	0.00	2192	2192	0.0	24541	24541	0.0
C7A0	0.87	0.80	0.04	15534	15509	-0.2	117554	117615	0.1
C8A0	0.80	0.53	0.10	13914	13645	-1.9	81326	82344	1.3
C9A0	0.56	0.50	0.57	15207	14758	-3.0	86360	87653	1.5
L1B0	0.34	1.00	0.32	1946	1848	-5.0	3663	3843	4.9
L1X9	0.41	0.00	0.23	1197	1193	-0.3	1513	1518	0.4
L4X0	0.80	0.71	0.15	19670	19099	-2.9	18152	19238	6.0
M1A1	0.34	0.48	0.13	8517	8467	-0.6	101113	101255	0.1
N1A2	0.58	0.87	0.64	4337	4316	-0.5	79637	79669	0.0
N1B1	0.89	1.00	0.57	1483	1477	-0.4	26664	26675	0.0
N3A0	0.71	0.38	0.00	42539	42401	-0.3	274139	274693	0.2
N5A1	0.55	0.82	0.00	42657	40649	-4.7	112294	117188	4.4
N5A9	0.89	0.00	0.00	9071	9069	-0.0	33114	33120	0.0
N5B3	0.00		0.00	1054	1053	-0.1	10569	10572	0.0
N6A4	0.76	0.79	0.34	13482	13322	-1.2	86964	87455	0.6
N6A9	0.72	0.36	0.04	11806	11797	-0.1	74626	74656	0.0
Total				151778	148982	-1.8	351881	354350	.7

Note: Quantity are average yearly standard units (on period 2002-2013). Δ *stands for the change of quantity between after and before in percentage of initial quantity. The parameter* ρ_{jm} *is the one estimated from the supply model in Canada and used for counterfactual simulations.*

Table 7.10: *Counterfactual Profits on All Drugs when International Reference Pricing w.r.t. Canada*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	33	33	1.8	4633	4633	-0.0
C2A2	0.66	0.48	0.00	783	783	0.0	6195	6195	0.0
C7A0	0.87	0.80	0.04	1505	1539	2.3	61310	61288	-0.0
C8A0	0.80	0.53	0.10	8385	9608	14.6	141424	139837	-1.1
C9A0	0.56	0.50	0.57	4815	7373	53.1	20654	19687	-4.7
L1B0	0.34	1.00	0.32	12479	30515	144.5	243432	183327	-24.7
L1X9	0.41	0.00	0.23	16275	17238	5.9	121461	120210	-1.0
L4X0	0.80	0.71	0.15	46707	71725	53.6	193670	175378	-9.4
M1A1	0.34	0.48	0.13	375	579	54.4	3640	3552	-2.4
N1A2	0.58	0.87	0.64	17924	19126	6.7	212219	212111	-0.1
N1B1	0.89	1.00	0.57	4954	5128	3.5	36128	36124	-0.0
N3A0	0.71	0.38	0.00	2857	3433	20.2	171438	171108	-0.2
N5A1	0.55	0.82	0.00	44548	99688	123.8	678053	600493	-11.4
N5A9	0.89	0.00	0.00	1101	1105	0.3	10707	10704	-0.0
N5B3	0.00		0.00	0	28		1827	1799	-1.5
N6A4	0.76	0.79	0.34	3221	4198	30.3	93089	92037	-1.1
N6A9	0.72	0.36	0.04	550	565	2.6	23932	23918	-0.1
Total				82066	126304	53.9	1392653	1310940	-5.8

Note: Profits are average yearly expenses in 1000 US$ (from the period 2002-2013). Δ stands for the change in profits between after and before in percentage of initial profits. The parameter ρ_j is the one estimated from the supply model in Canada and used for counterfactual simulations.

Table 7.11: *Counterfactual Profits on All Drugs when International Reference Pricing w.r.t. Six Countries*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	33	33	1.8	4633	4632	-0.0
C2A2	0.66	0.48	0.00	783	783	0.0	6195	6195	0.0
C7A0	0.87	0.80	0.04	1505	1539	2.3	61310	61178	-0.2
C8A0	0.80	0.53	0.10	8385	9412	12.2	141424	134072	-5.2
C9A0	0.56	0.50	0.57	4815	6775	40.7	20654	17714	-14.2
L1B0	0.34	1.00	0.32	12479	26205	110.0	243432	155233	-36.2
L1X9	0.41	0.00	0.23	16275	16843	3.5	121461	118860	-2.1
L4X0	0.80	0.71	0.15	46707	58642	25.6	193670	147267	-24.0
M1A1	0.34	0.48	0.13	375	560	49.3	3640	3420	-6.1
N1A2	0.58	0.87	0.64	17924	19050	6.3	212219	211672	-0.3
N1B1	0.89	1.00	0.57	4954	5119	3.3	36128	36103	-0.1
N3A0	0.71	0.38	0.00	2857	3379	18.3	171438	169661	-1.0
N5A1	0.55	0.82	0.00	44548	80420	80.5	678053	491980	-27.4
N5A9	0.89	0.00	0.00	1101	1104	0.3	10707	10695	-0.1
N5B3	0.00		0.00	0	28		1827	1800	-1.5
N6A4	0.76	0.79	0.34	3221	4084	26.8	93089	88176	-5.3
N6A9	0.72	0.36	0.04	550	564	2.5	23932	23866	-0.3
Total				63550	102984	62	928499	783149	-15.6

Note: Profits are average yearly expenses in 1000 US$ (from the period 2002-2013). Δ stands for the change in profits between after and before in percentage of initial profits. The parameter ρ_j is the one estimated from the supply model in Canada and used for counterfactual simulations.

Table 7.12: *Counterfactual Expenses on Patented Drugs when International Reference Pricing w.r.t. Canada*

		ρ_{jm}		Canada			US		
ATC4	*On Patent*	*Branded Off*	*Generic*	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	17	16	-3.5	3764	3764	0.0
C2A2	0.66	0.48	0.00	801	801	0.0	9342	9342	0.0
C7A0	0.87	0.80	0.04	819	800	-2.3	69644	69652	0.0
C8A0	0.80	0.53	0.10	7351	8016	9.1	74427	74297	-0.2
C9A0	0.56	0.50	0.57	6647	8694	30.8	23929	24776	3.5
L1B0	0.34	1.00	0.32	26137	40586	55.3	354028	289568	-18.2
L1X9	0.41	0.00	0.23	27066	27806	2.7	183792	182655	-0.6
L4X0	0.80	0.71	0.15	52375	76385	45.8	232537	213420	-8.2
M1A1	0.34	0.48	0.13	457	423	-7.4	3405	3721	9.3
N1A2	0.58	0.87	0.64	1752	1654	-5.6	131440	131950	0.4
N1B1	0.89	1.00	0.57	1839	1841	0.1	41420	41465	0.1
N3A0	0.71	0.38	0.00	3499	3424	-2.2	194414	194818	0.2
N5A1	0.55	0.82	0.00	28076	61149	117.8	849308	774450	-8.8
N5A9	0.89	0.00	0.00	1312	1312	0.0	2207	2210	0.1
N5B3	0.00		0.00	29	35	19.7	2858	3124	9.3
N6A4	0.76	0.79	0.34	2473	2994	21.1	108980	108315	-0.6
N6A9	0.72	0.36	0.04	415	411	-0.9	5774	5787	0.2
Total				109172	148375	35.9	1468652	1395084	-5

Note: Expenses are average yearly expenses in 1000 US$ (on period 2002-2013). Patented drugs only.

Table 7.13: *Counterfactual Expenses on Patented Drugs when International Reference Pricing w.r.t. Six Countries*

				Canada			US		
		ρ_{jm}							
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	0.91	0.51	0.00	17	16	-3.5	3764	3766	0.1
C2A2	0.66	0.48	0.00	801	801	0.0	9342	9342	0.0
C7A0	0.87	0.80	0.04	819	801	-2.3	69644	69687	0.1
C8A0	0.80	0.53	0.10	7351	7916	7.7	74427	73537	-1.2
C9A0	0.56	0.50	0.57	6647	8221	23.7	23929	25263	5.6
L1B0	0.34	1.00	0.32	26137	37330	42.8	354028	267372	-24.5
L1X9	0.41	0.00	0.23	27066	27521	1.7	183792	181867	-1.0
L4X0	0.80	0.71	0.15	52375	63768	21.8	232537	184170	-20.8
M1A1	0.34	0.48	0.13	457	428	-6.4	3405	3922	15.2
N1A2	0.58	0.87	0.64	1752	1666	-4.9	131440	133250	1.4
N1B1	0.89	1.00	0.57	1839	1841	0.1	41420	41672	0.6
N3A0	0.71	0.38	0.00	3499	3429	-2.0	194414	195977	0.8
N5A1	0.55	0.82	0.00	28076	49148	75.1	849308	667724	-21.4
N5A9	0.89	0.00	0.00	1312	1312	0.0	2207	2218	0.5
N5B3	0.00		0.00	29	35	19.7	2858	3122	9.3
N6A4	0.76	0.79	0.34	2473	2931	18.5	108980	105845	-2.9
N6A9	0.72	0.36	0.04	415	411	-0.9	5774	5839	1.1
Total				45079	68092	51.05	995592	860347	-13.58

Note: Expenses are average yearly expenses in 1000 US$ (on period 2002-2013). Patented drugs only.

Table 7.14: *Counterfactual Price Changes by ATC-4 when International Reference Pricing w.r.t. Canada*

ATC4	ρ_{jm} On Patent	ρ_{jm} Branded Off	ρ_{jm} Generic	Price Change All drugs CA (%)	Price Change All drugs US (%)	Price Change Patented CA (%)	Price Change Patented US (%)	Price Change Branded Off CA (%)	Price Change Branded Off US (%)	Price Change Generic CA (%)	Price Change Generic US (%)
A10H0	0.91	0.51	0.00	1.4	-0.0	63.0	-0.0	0.0	-0.0	0.0	0.0
C2A2	0.66	0.48	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C7A0	0.87	0.80	0.04	7.2	-0.1	56.0	-0.1	-2.1	-0.0	-0.0	0.0
C8A0	0.80	0.53	0.10	22.1	-1.0	74.0	-3.2	2.0	-0.1	0.2	0.0
C9A0	0.56	0.50	0.57	33.7	-6.3	87.4	-13.9	0.7	-0.9	1.9	0.0
L1B0	0.34	1.00	0.32	44.7	-10.8	107.5	-12.4	-17.6	-1.5	0.2	0.0
L1X9	0.41	0.00	0.23	2.6	-0.7	5.3	-0.8	0.0	0.0	0.6	0.0
L4X0	0.80	0.71	0.15	32.5	-3.4	71.9	-6.6	2.9	-1.8	-0.3	0.0
M1A1	0.34	0.48	0.13	29.4	-1.6	211.7	-12.5	0.4	-0.1	0.3	0.0
N1A2	0.58	0.87	0.64	7.2	-0.2	141.1	-0.7	6.2	-0.0	1.7	0.0
N1B1	0.89	1.00	0.57	4.1	-0.1	23.2	-0.3	2.6	-0.0	2.0	0.0
N3A0	0.71	0.38	0.00	21.1	-0.3	137.3	-0.7	0.2	-0.0	0.0	0.0
N5A1	0.55	0.82	0.00	63.6	-8.7	257.4	-10.0	37.1	-0.2	0.0	0.0
N5A9	0.89	0.00	0.00	0.4	-0.0	1.7	-0.2	0.0	-0.0	0.0	0.0
N5B3	0.00		0.00	181.7	-7.1	1713.4	-14.3	0.0	0.0	0.0	0.0
N6A4	0.76	0.79	0.34	33.8	-1.2	156.6	-1.6	7.3	-0.5	1.1	0.0
N6A9	0.72	0.36	0.04	3.6	-0.1	40.6	-0.6	-0.1	-0.0	-0.0	0.0

Note: Changes in % of initial price using market shares weighted average prices.

Table 7.15: *Counterfactual Price Changes by ATC-4 when International Reference Pricing w.r.t. Six Countries*

ATC4	ρ_{jm} On Patent	ρ_{jm} Branded Off	ρ_{jm} Generic	Price Change All drugs CA (%)	Price Change All drugs US (%)	Price Change Patented CA (%)	Price Change Patented US (%)	Price Change Branded Off CA (%)	Price Change Branded Off US (%)	Price Change Generic CA (%)	Price Change Generic US (%)
A10H0	0.91	0.51	0.00	1.4	-0.1	62.8	-0.2	0.0	-0.0	0.0	0.0
C2A2	0.66	0.48	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C7A0	0.87	0.80	0.04	6.9	-0.3	53.9	-0.5	-2.1	-0.0	-0.0	0.0
C8A0	0.80	0.53	0.10	16.5	-4.2	55.4	-13.2	1.6	-0.3	0.2	0.0
C9A0	0.56	0.50	0.57	21.2	-12.1	54.9	-26.4	0.5	-2.3	1.3	0.0
L1B0	0.34	1.00	0.32	30.9	-17.5	74.6	-20.2	-17.9	-2.1	-0.0	0.0
L1X9	0.41	0.00	0.23	1.5	-1.8	3.1	-2.0	0.0	0.0	0.4	0.0
L4X0	0.80	0.71	0.15	14.0	-7.2	31.0	-14.0	1.9	-4.6	-0.2	0.0
M1A1	0.34	0.48	0.13	22.0	-2.3	158.0	-17.9	0.3	-0.1	0.3	0.0
N1A2	0.58	0.87	0.64	6.1	-0.6	114.1	-2.3	5.9	-0.1	1.6	0.0
N1B1	0.89	1.00	0.57	3.9	-0.5	21.8	-1.5	2.5	-0.1	1.9	0.0
N3A0	0.71	0.38	0.00	17.1	-1.3	111.4	-2.9	0.1	-0.1	0.0	0.0
N5A1	0.55	0.82	0.00	38.9	-18.5	156.7	-21.5	23.1	-0.6	0.0	0.0
N5A9	0.89	0.00	0.00	0.3	-0.0	1.3	-0.9	0.0	-0.0	0.0	0.0
N5B3	0.00		0.00	181.7	-7.1	1713.4	-14.3	0.0	0.0	0.0	0.0
N6A4	0.76	0.79	0.34	26.8	-5.3	123.9	-6.9	5.9	-2.0	0.9	0.0
N6A9	0.72	0.36	0.04	3.3	-0.3	37.3	-3.1	-0.2	-0.1	-0.0	0.0

Note: Changes in % of initial price using market shares weighted average prices.

Table 7.16: *Counterfactual Prices of Drugs on Patent present in both US and Canada when International Reference Pricing w.r.t. Six Countries*

	Before		After			
	Canada	US	Canada		US	
ATC4	Price	Price	Price	Δ (%)	Price	Δ (%)
A10H0	0.63	1.03	1.03	62.31	1.03	-0.20
C2A2	57.76	17.32	57.76	0.00	17.32	0.00
C7A0	1.08	1.95	2.00	85.47	1.91	-2.25
C8A0	1.06	2.19	1.88	77.37	1.88	-14.16
C9A0	0.55	1.78	1.16	110.32	1.16	-34.75
L1B0	247.97	506.81	372.30	50.14	372.30	-26.54
L1X9	545.32	579.99	579.44	6.26	556.10	-4.12
L4X0	4.98	10.03	6.54	31.34	6.31	-37.11
M1A1	0.67	3.07	1.79	166.46	1.79	-41.63
N1A2	21.11	51.54	45.65	116.26	45.65	-11.42
N1B1	12.56	16.47	16.19	28.95	16.19	-1.66
N3A0	1.55	3.79	3.52	126.17	3.52	-7.14
N5A1	2.75	13.51	10.57	284.52	10.57	-21.78
N5A9	0.82	1.36	1.21	47.29	1.22	-10.70
N5B3	2.67	61.87	52.46	1863.08	52.51	-15.12
N6A4	1.53	3.68	3.38	120.54	3.38	-8.11
N6A9	0.39	1.15	0.98	152.76	0.98	-14.63

Note: Market shares weighted average price of patented drugs by ATC-4, country for drugs present in both only. Percentage changes are changes with respect to the initial situation.

Table 7.17: *Counterfactual Consumer Welfare Changes on All Drugs when International Reference Pricing w.r.t. Canada*

	Canada			US		
ATC4	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	39835	39824	-0.0	111958	111960	0.0
C2A2	11807	11807	0.0	82759	82759	0.0
C7A0	78531	78312	-0.3	376421	376471	0.0
C8A0	71924	68689	-4.5	262422	264091	0.6
C9A0	77971	72234	-7.4	280640	284298	1.3
L1B0	10520	9220	-12.4	11972	12953	8.2
L1X9	6327	6286	-0.6	4997	5013	0.3
L4X0	104068	94355	-9.3	56111	59567	6.2
M1A1	44613	44072	-1.2	337359	337733	0.1
N1A2	22889	22654	-1.0	260498	260540	0.0
N1B1	7581	7520	-0.8	85787	85798	0.0
N3A0	223974	222397	-0.7	890829	891513	0.1
N5A1	224108	200673	-10.5	348676	369068	5.8
N5A9	45364	45346	-0.0	108728	108734	0.0
N5B3	5520	5511	-0.2	37825	37842	0.0
N6A4	69080	67444	-2.4	269684	270486	0.3
N6A9	59708	59622	-0.1	240621	240654	0.0
Total	239087	227859	-4.6	3221244	3248920	.8

Note: Welfare values are average yearly on period 2002-2013 scaled by market size. Δ stands for the change of welfare between after and before in percentage of initial welfare. The parameter ρ_{jm} is the one estimated from the supply model in Canada and used for counterfactual simulations.

Table 7.18: *Counterfactual Expenses and Profits Global Changes on All Drugs when International Reference Pricing w.r.t. Canada*

	Expenses			Profits		
ATC4	Before	After	Δ (%)	Before	After	Δ (%)
A10H0	11456	11456	-0.0	4665	4666	0.0
C2A2	35585	35585	0.0	6978	6978	0.0
C7A0	137869	137869	-0.0	62815	62827	0.0
C8A0	253424	252070	-0.5	149809	149445	-0.2
C9A0	60946	63477	4.2	25469	27061	6.2
L1B0	440688	384941	-12.6	255911	213842	-16.4
L1X9	229428	228917	-0.2	137736	137449	-0.2
L4X0	536485	516910	-3.6	240376	247103	2.8
M1A1	28055	28341	1.0	4015	4131	2.9
N1A2	625829	627110	0.2	230143	231237	0.5
N1B1	120932	121098	0.1	41082	41252	0.4
N3A0	447337	447414	0.0	174295	174541	0.1
N5A1	1037164	1013646	-2.3	722601	700181	-3.1
N5A9	53672	53670	-0.0	11808	11809	0.0
N5B3	5994	6262	4.5	1827	1827	-0.0
N6A4	149428	149451	0.0	96310	96235	-0.1
N6A9	56676	56679	0.0	24482	24483	0.0
Total	4230967	4134897	-2.2	2190321	2135067	-2.5

Note: All values are average yearly on period 2002-2013, summing US and Canada. Δ stands for the change between after and before in percentage of initial value.

Table 7.19: *Counterfactual Prices when International Reference Pricing w.r.t. Canada*

	All				Patented				Branded Off				Generic			
	Before		After		Before		After		Before		After		Before		After	
ATC4	CA	US	CA	US	CA	US	CA	US	CA	US	CA	US	CA	US	CA	US
A10H0	0.05	0.35	0.05	0.35	0.64	1.04	1.05	1.04	0.35	0.79	0.35	0.79	0.05	0.20	0.05	0.20
C2A2	0.67	1.38	0.67	1.38	55.32	12.43	55.32	12.43	4.03	2.24	4.03	2.24	0.15	1.05	0.15	1.05
C7A0	0.19	1.14	0.22	1.14	0.32	6.91	0.49	6.91	1.41	1.49	1.38	1.49	0.10	0.45	0.10	0.45
C8A0	0.89	2.99	1.29	2.96	1.25	2.30	2.18	2.22	0.78	17.56	0.80	17.55	0.50	1.38	0.51	1.38
C9A0	0.57	0.60	0.95	0.56	0.66	1.67	1.24	1.43	0.54	1.51	0.55	1.50	0.31	0.33	0.32	0.33
L1B0	17.25	113.27	32.67	101.04	19.64	333.05	40.75	291.63	12.74	125.50	10.51	123.57	10.42	18.16	10.43	18.16
L1X9	21.49	130.27	22.59	129.33	420.67	734.94	443.17	729.15	0.94		0.94		0.89	14.23	0.90	14.23
L4X0	2.95	25.87	4.87	25.00	2.97	27.02	5.10	25.23	2.66	9.57	2.74	9.40	2.87	38.32	2.86	38.32
M1A1	0.20	0.26	0.31	0.26	0.67	3.67	2.09	3.21	0.50	0.91	0.50	0.91	0.13	0.21	0.13	0.21
N1A2	5.29	7.68	6.05	7.67	11.55	74.26	27.84	73.74	6.52	15.68	6.92	15.67	4.51	4.61	4.58	4.61
N1B1	4.35	4.30	4.70	4.30	11.10	15.77	13.68	15.73	4.52	6.00	4.64	5.99	3.15	2.83	3.21	2.83
N3A0	0.26	1.58	0.38	1.58	1.37	4.28	3.25	4.25	0.19	4.70	0.19	4.70	0.20	0.83	0.20	0.83
N5A1	1.67	8.59	3.80	7.85	1.85	10.69	6.61	9.62	3.11	9.73	4.27	9.71	0.40	3.17	0.40	3.17
N5A9	0.29	1.54	0.29	1.54	1.98	2.36	2.02	2.36	0.25	14.27	0.25	14.27	0.14	1.11	0.14	1.11
N5B3	0.14	0.56	0.63	0.52	2.08	26.51	37.67	22.71					0.11	0.29	0.11	0.29
N6A4	0.47	1.65	0.78	1.63	1.33	3.61	3.40	3.56	1.43	4.17	1.54	4.15	0.30	0.47	0.30	0.47
N6A9	0.21	0.71	0.23	0.71	0.63	2.83	0.88	2.81	0.61	3.43	0.61	3.43	0.15	0.33	0.15	0.33

Note: Market shares weighted average price by ATC-4, country.

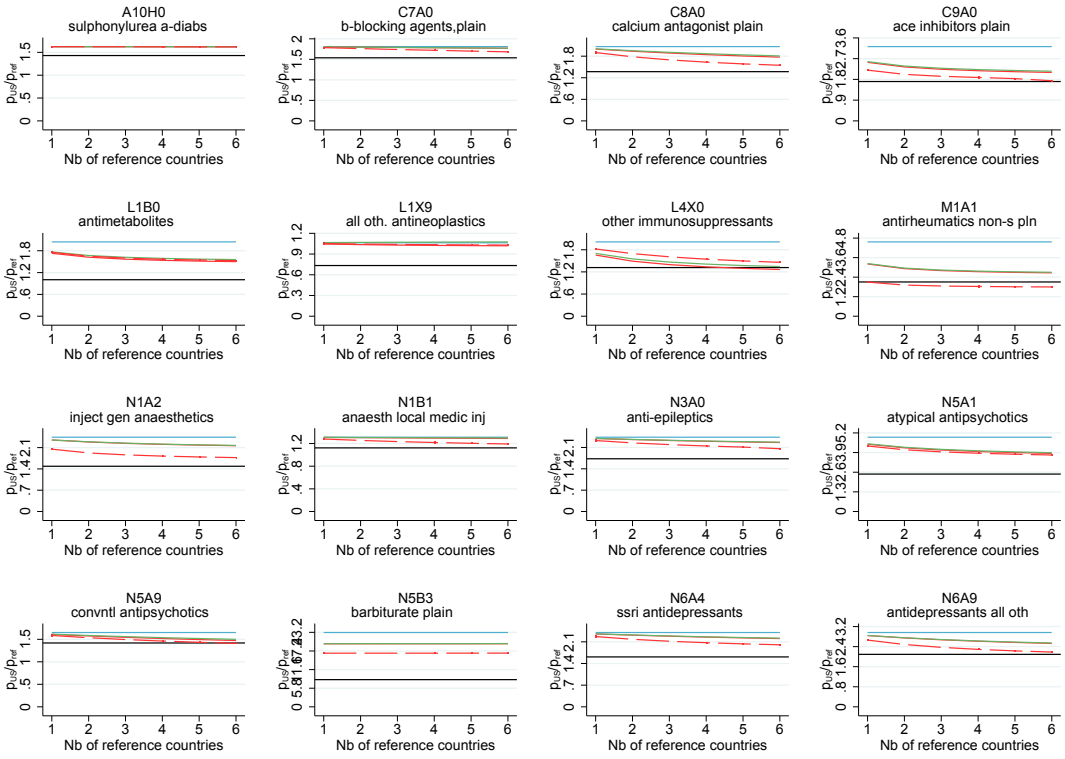
Table 7.20: *Counterfactual Prices when International Reference Pricing w.r.t. Six countries*

	All				Patented				Branded Off				Generic			
	Before		After		Before		After		Before		After		Before		After	
ATC4	CA	US	CA	US	CA	US	CA	US	CA	US	CA	US	CA	US	CA	US
A10H0	0.05	0.35	0.05	0.35	0.64	1.04	1.05	1.03	0.35	0.79	0.35	0.79	0.05	0.20	0.05	0.20
C2A2	0.67	1.38	0.67	1.38	55.32	12.43	55.32	12.43	4.03	2.24	4.03	2.24	0.15	1.05	0.15	1.05
C7A0	0.19	1.14	0.22	1.14	0.32	6.91	0.49	6.88	1.41	1.49	1.38	1.48	0.10	0.45	0.10	0.45
C8A0	0.89	2.99	1.19	2.87	1.25	2.30	1.95	1.99	0.78	17.56	0.80	17.52	0.50	1.38	0.51	1.38
C9A0	0.57	0.60	0.81	0.53	0.66	1.67	1.03	1.23	0.54	1.51	0.54	1.47	0.31	0.33	0.32	0.33
L1B0	17.25	113.27	27.92	93.46	19.64	333.05	34.28	265.90	12.74	125.50	10.46	122.90	10.42	18.16	10.42	18.16
L1X9	21.49	130.27	22.13	127.93	420.67	734.94	433.75	720.46	0.94		0.94		0.89	14.23	0.90	14.23
L4X0	2.95	25.87	3.78	24.01	2.97	27.02	3.89	23.24	2.66	9.57	2.71	9.13	2.87	38.32	2.86	38.32
M1A1	0.20	0.26	0.28	0.26	0.67	3.67	1.73	3.01	0.50	0.91	0.50	0.91	0.13	0.21	0.13	0.21
N1A2	5.29	7.68	5.93	7.64	11.55	74.26	24.72	72.53	6.52	15.68	6.90	15.66	4.51	4.61	4.58	4.61
N1B1	4.35	4.30	4.68	4.28	11.10	15.77	13.52	15.54	4.52	6.00	4.64	5.99	3.15	2.83	3.21	2.83
N3A0	0.26	1.58	0.36	1.56	1.37	4.28	2.90	4.16	0.19	4.70	0.19	4.70	0.20	0.83	0.20	0.83
N5A1	1.67	8.59	2.97	7.00	1.85	10.69	4.75	8.40	3.11	9.73	3.83	9.67	0.40	3.17	0.40	3.17
N5A9	0.29	1.54	0.29	1.54	1.98	2.36	2.01	2.34	0.25	14.27	0.25	14.27	0.14	1.11	0.14	1.11
N5B3	0.14	0.56	0.63	0.52	2.08	26.51	37.67	22.73					0.11	0.29	0.11	0.29
N6A4	0.47	1.65	0.72	1.56	1.33	3.61	2.97	3.37	1.43	4.17	1.52	4.09	0.30	0.47	0.30	0.47
N6A9	0.21	0.71	0.23	0.71	0.63	2.83	0.86	2.74	0.61	3.43	0.61	3.43	0.15	0.33	0.15	0.33

Note: Market shares weighted average price by ATC-4, country.

7.7 Additional Figures of counterfactuals

Figure 7.2: *Relative Price US vs Canada under Different Counterfactual Policies*



Note: Log relative mean prices for on patent drugs in the US versus Canada, by ATC4, without weighting by market share.
— Statu quo — IRF – – IRF with Reference Half US Size — IRF with 10% MFN – IRF with required comparison