Bargaining and International Reference Pricing in the Pharmaceutical Industry

Pierre Dubois*   Ashvin Gandhi†   Shoshana Vasserman‡

November 16, 2018§

Abstract

The United States spends twice as much per person on pharmaceuticals as European countries, in large part because prices are higher in the US. This fact has led policymakers in the US to consider legislation for price controls. This paper assesses the effects of a hypothetical US reference pricing policy that would cap prices in US markets by those offered in Canada. We estimate a structural model of demand and supply for pharmaceuticals in the US and Canada, in which Canadian prices are set through a negotiation process between pharmaceutical companies and the Canadian government. We then simulate the impacts of the counterfactual international reference pricing rule, allowing firms to internalize the cross-country impacts of their prices both when setting prices in the US and when negotiating prices in Canada. We find that such a policy results in a slight decrease in US prices and a substantial increase in Canadian prices. The magnitude of these effects depends on the particular structure of the policy. Overall, we find modest consumer welfare gains in the US but substantial consumer welfare losses in Canada. Moreover, we find that pharmaceutical profits increase in net, suggesting that reference pricing of this form would constitute a net transfer from consumers to firms.

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

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

*Toulouse School of Economics, University of Toulouse Capitole, pierre.dubois@tse-fr.eu

†Harvard University, Department of Economics, agandhi@fas.harvard.edu

‡Harvard University, Department of Economics, svasserman@fas.harvard.edu

§We thank Isis Durrmeyer, Matthew Grennan, Darius Lakdawalla, Robin Lee, Patrick Rey, Howard Smith for useful comments and discussions.

1 Introduction

The pharmaceutical industry represents a significant part of the global economy: global pharmaceutical sales amounted to \$1.1 trillion in 2016, one third 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 (2018), Lakdawalla et al. (2009)). Innovating new drugs is expensive: the Pharmaceutical Research and Manufacturers of America (PhRMA) estimates that the average cost to develop a drug (including the cost of failure) has increased from \$140 million in the 1970s to \$1.2 billion in the early 2000s (both in adjusted 2000 dollars), and only 2 out of 10 drugs ever achieve sufficient revenue to cover these R&D costs.[2] 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).[3] 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. New drugs are generally protected from competition by patents in order to ensure adequate profitability, and breakthrough drug prices often greatly exceed their marginal costs of production. For example, Gilead Sciences recently priced its breakthrough hepatitis C drug, Sovaldi, at \$1,000 per pill—a price that almost certainly exceeds its marginal cost.[4] Even in less extreme cases, margins can be substantial: Dubois and Lasio (2018) find margins in the range of 10-50% in the French anti-ulcer industry—in spite of French price constraints—and Linnosmaa et al. (2004) estimate Finnish drug margins to be in the range of 59-67%.

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 this topic—see, for example, Helpman (1993) and Grossman and Lai (2004)—there is very limited empirical work. One notable exception is Chaudhuri et al. (2006), which examines quinolone sales data to determine the effect of TRIPS global patent protection on welfare. Chaudhuri et. al. 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) 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

[1] QuintilesIMS Global Pharma Outlook 2016.
[2] PhRMA 2014 profile.
[3] To obtain these numbers, we adjusted the figures reported in the papers for inflation.
[4] "Sales of Sovaldi, New Gilead Hepatitis C Drug, Soar to \$10.3 Billion." Feb. 3, 2015. *New York Times*.

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 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—not only because of larger consumption but also because of substantially higher prices—price controls in the US are increasingly being called for in policy circles (Salter, 2015; OECD, 2017), as well as, recently, by the US administration.[5] 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. Most price control policies base price negotiations 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.

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 country. 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 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

[5] See New York Times, October 25, 2018: "Trump Proposes to Lower Drug Prices by Basing Them on Other Countries' Costs".

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 Canadian price setting when negotiating with the US.[6] 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.[7]

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 centralized regulator under a Nash bargaining equilibrium (Horn and Wolinsky, 1988; Crawford and Yurukoglu, 2012; Grennan, 2013; Gowrisankaran et al., 2015). With these supply side assumptions, we are able to separately identify costs and bargaining parameters.[8] 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.

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, while simultaneously price negotiations in Canada 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 Canadian prices. The magnitude of these effects depends on the particular structure of the policy. The effect appears to be asymmetric because of the size differences in pharmaceutical markets across countries, the bargaining parameter value in Canada, 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 Canada. Moreover, we find that pharmaceutical profits increase in net, suggesting that reference pricing of this form would constitute a net transfer

[6] 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.

[7] Danzon and Chao (2000a) and Danzon et al. (2005) also study the equilibrium effects of international reference pricing, examining its effects on delayed entries of new drugs in reference countries.

[8] Dubois and Lasio (2018) instead chooses to model price setting in France as setting price ceilings that constrain firms.

from consumers to firms. 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 (2000b), Danzon et al. (2005), Maini and Pammoli (2017)). Our analysis holds entry/exit fixed and so it does not internalize such an effect. Moreover, while our analysis shows the effects on consumer welfare and manufacturing profits, it likely underestimates the long-term welfare impact as revealed preferences from current consumers and regulators' behavior probably do not fully internalize the trade-off between current and future generations.

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 Pharmaceuticals Data

We use data from IMS Health on revenues and quantities of drugs 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 to construct instrumental variables for our identification strategy. 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 aggregate drugs across multiple dosage forms and administering methods (e.g., tablets and injections) using "standard units", the minimal dosage of a given drug. We use the international drug name in the data to match drug names across countries. We aggregate sales to the molecule-corporation-market level and aggregate generics for each molecule. 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 compute quarterly drug prices as the ratio of total revenue and total quantity in standard units.

Our data details each drug's Anatomical Therapeutic Chemical (ATC) Class. In the ATC system, all drugs are classified into groups at five different (nested) levels. Our data contains the fifth ATC classification level (ATC-5) for each drug. 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.

We define markets at the ATC-4 class level. Table 2.1 shows descriptive statistics on the number of molecules by on-patent/off-patent branded and generic stats by ATC-4 class across the US and Canada as well as the expenditure share that each class represents in the data for the hospital sector. The table shows these statistics for the 31 ATC-4 classes for which we have at least one on-patent molecule in Canada and the US. When all molecules' patents are expired within an ATC-4 class, this means that most drugs are generics and thus inexpensive. In this case, lowering prices in the US is of less interest. Moreover, we also remove from our analysis the ATC-4 classes for which Canada has no on-patent molecule while the US does (this happens mostly because of the delayed entry of new molecules in Canada), in which case there is no on-patent molecule reference for the US molecule. These 31 ATC-4 classes are from the following ATC-3 classes: antiulcerants (A2B), heparins (B1B) which are antitrhombotic agents, antihypertensives (C2A), beta-blocking agents (C7A), calcium antagonists (C8A), ACE inhibitors (C9A), cholesterol- and triglyceride-regulating preparations (C10A), alkylating agents (L1A) that are antineoplastics (ATC-2 L1), antimetabolites (L1B), plant-based antineoplastics (L1C), antineoplastic antibiotics (L1D), other antineoplastics (L1X), cytostatic hormone antagonists (L2B), other immunosuppressants (L4X), nonsteroidal antirheumatics (M1A), bone calcium regulators (M5B), general anesthetics (N1A), local anesthetics (N1B), narcotics (N2A), nonnarcotics and antipyretics (N2B), antiepileptics (N3A), antipsychotics (N5A), and antidepressants and mood stabilizers (N6A). These drugs markets represent 93% of total hospital drug expenses in the US and 72% in Canada.

Table 2.1 shows that in Canada, anti-cancer drugs (L1 class) represent a relatively larger share of total expenses (around 35%) while they represent 20% in the US. By contrast, the share of US spending to anti-thrombotic agents is much larger (16.8%) than in Canada (7.9%). The structure of relative expenses is thus different even if the US spends much more in value in all classes and pays much higher prices on almost all drugs as shown by Table 7.1 in Appendix 7.1. Of course, the composition of drugs sold within each class in each country is different, but even the ATC-4 level average prices are almost always much higher in the US. In fact, there is likely to be a negative correlation between prices and quantities within each class that makes the average price by ATC-4 class potentially less different across countries, in addition to the fact that some expensive drugs are sometimes not even sold in the US.

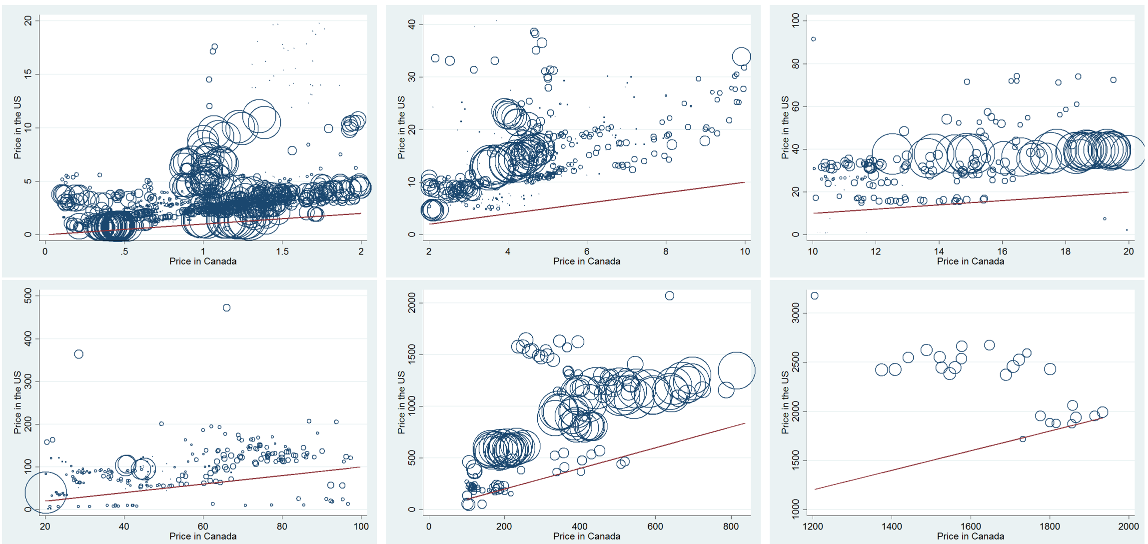
Table 2.1: *Number of molecules and expenditure shares by ATC-4*

		Canada				US			
		Number				Number			
ATC4	Label	On Patent	Branded Off Patent	Generics	Expenditure Share (%)	On Patent	Branded Off Patent	Generics	Expenditure Share (%)
A10C1	H INSUL+ANG FAST ACT	3	0	0	0.66	4	0	0	1.16
A2B2	ACID PUMP INHIBITORS	1	4	4	3.36	4	4	4	4.12
B1B2	FRACTIONATED HEPARINS	4	0	0	7.98	3	0	0	16.81
C10A1	STATINS (HMG-COA RED	3	1	3	3.19	3	3	3	2.39
C2A2	ANTIHYPER.PL MAINLY PERI	1	2	4	0.32	2	1	4	0.51
C7A0	B-BLOCKING AGENTS,PLAIN	2	3	10	1.22	2	8	12	2.18
C8A0	CALCIUM ANTAGONIST PLAIN	1	4	4	1.90	1	6	7	2.50
C9A0	ACE INHIBITORS PLAIN	9	1	2	1.55	6	3	5	0.58
C9C0	ANGIOTEN-II ANTAG, PLAIN	2	4	5	1.10	5	3	3	0.96
L1A0	ALKYLATING AGENTS	6	2	3	1.75	9	4	5	2.06
L1B0	ANTIMETABOLITES	7	1	3	7.90	5	3	7	6.84
L1C0	VINCA ALKALOIDS	3	3	5	10.84	4	3	5	4.79
L1D0	ANTINEOPLAS. ANTIBIOTICS	3	3	5	4.07	4	4	5	2.17
L1X4	A-NEO PROTEIN KINASE INH	8	0	0	9.31	10	0	0	0.96
L1X9	ALL OTH. ANTINEOPLASTICS	2	1	2	2.67	7	0	3	1.26
L2B2	CYTO ANTI-ANDROGENS	1	2	3	0.91	1	1	2	0.11
L2B3	CYTOSTAT AROMATASE INHIB	3	0	0	1.87	4	0	0	0.14
L4X0	OTHER IMMUNOSUPPRESSANTS	5	1	2	3.72	9	3	4	1.75
M1A1	ANTIRHEUMATICS NON-S PLN	1	4	7	0.38	2	8	12	0.40
M5B3	BISPHOSPH OSTEOPOROSIS	2	2	3	0.59	4	2	2	0.47
N1A1	INHAL GEN ANAESTHETICS	1	2	2	3.68	1	2	2	8.26
N1A2	INJECT GEN ANAESTHETICS	2	4	6	2.27	3	6	8	6.36
N1B1	ANAESTH LOCAL MEDIC INJ	2	3	3	0.98	1	2	5	1.12
N1B3	ANAESTH LOCAL TOPICAL	1	1	2	1.73	3	2	3	1.16
N2A0	NARCOTIC ANALGESICS	1	5	10	5.19	1	4	17	7.06
N2B0	NON-NARCOTIC ANALGESICS	1	6	8	0.56	2	5	15	0.93
N3A0	ANTI-EPILEPTICS	4	5	8	2.71	12	3	7	6.67
N5A1	ATYPICAL ANTIPSYCHOTICS	3	1	1	14.81	5	1	1	13.16
N5A9	CONVNTL ANTIPSYCHOTICS	7	4	8	1.13	3	4	8	0.71
N6A4	SSRI ANTIDEPRESSANTS	1	4	5	1.11	1	3	5	1.70
N6A9	ANTIDEPRESSANTS ALL OTH	3	3	12	0.54	5	9	12	0.71

Note: Average number of molecules (rounded to closest integer) and expenditure shares within country over 2002-2013, by ATC-4 classes. Some ATC-4 abbreviated labels have been revised and are not used anymore. See details of classification in European Pharmaceutical Market Research Association (2018).

For the drugs that are present in both the US and Canada, it is interesting to check 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 prices in the US against prices in Canada for the on-patent drugs present in both countries and for different ranges of prices in $US per standard unit. As shown in the figure, most of 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. The ratio of prices between the US and Canada slightly decreases, however, so that the most expensive drugs are priced similarly across the two countries.

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



Note: Graphs for different scales of the price in Canada because of the enormous variation of prices of drugs in $US per standard unit. Within each graph, the circle size is proportional to the sales value of this drug in the US.

Using this data, we estimate demand for prescription drugs, using a standard demand model as described below.

3 Demand Model

We use standard flexible demand models that allow us to identify and estimate the aggregate shape of demand. Consumer price elasticity is a major consideration in price determination for both manufacturers and regulators. As such, accurately estimating demand is key to our counterfactual predictions. As we cannot observe data on the behavior of insurers, healthcare providers and other intermediaries between patients and drug manufacturers, we abstract away from modeling them and do not disentangle their role in the aggregate revealed preferences.

3.1 Demand Specification

We start by modeling the demand of pharmaceuticals in hospitals, by country and quarter within each drug market. We segment drug markets using the level 4 Anatomical Therapeutic Chemical Class and country-quarters. We use the standard Berry et al. (1995) and Nevo (2001) models for differentiated product markets using a random coefficient logit demand model for the decision maker. For each country, we assume that the utility for an individual i purchasing drug j during quarter t is, for $j = 0, 1, .., J_m$ and all ATC-4 drug classes m:

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

where

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

and u_{i0t} is normalized to zero, p_{jt} is the price at t of drug j belonging to drug market $m(j)$, g_j is a dummy variable indicating if drug j is branded, x_j another dummy variable indicating whether the molecule patent has expired or not, ϕ_j is a molecule fixed effect, γ_i is a random effect for inside goods only, α_i a random coefficient on the price disutility[9] and β_{im} a random coefficient on the branded (nongeneric) dummy with market specific mean, and ξ_{jt} is a product unobserved effect. 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 $\theta = (\sigma_\alpha, \sigma_\beta, \sigma_\gamma)$ and $\delta_{jt} = \alpha \ln p_{jt} + \beta_{m(j)} g_j + \lambda_{m(j)} x_j + \phi_j + \mu_{m(j)t}$. In this specification, all parameters are country-specific.

Assuming that ε_{ijt} is i.i.d. extreme value distributed, the aggregate choice probability of product j in market mt where $m = m(j)$ is:

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

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

[9] 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.

3.2 Demand Identification

We thus estimate our demand model using the traditional BLP method with instrumental variables for prices (Berry et al., 1995). Candidate instruments are BLP-style or Hausman-style instruments.

With instruments Z_{jt} that are orthogonal to the demand shocks, $\xi_{jt}(\delta_{jt}, s_{jt}, \theta)$ defined by inverting the system of theoretical market shares equaling observed market shares. The BLP estimation method uses GMM with the moment condition:

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

Identifying the price coefficient distribution is more challenging, since we expect the price-setting process to be affected by unobserved demand shocks ξ_{jt}. We need instruments that affect prices but are orthogonal to ξ_{jt}. Since we examine a large number of drugs across a large number of classes, we are unlikely to find cost-shifters that are relevant to all classes in order to instrument for prices, and collecting many class or drug-specific cost-shifters is unfeasible. One possibility would be to restrict our analysis to a few therapeutic classes and find appropriate cost shifters and then identify the price coefficient only off of those therapeutic classes. However, this would limit the scope of our empirical assessment of the effect of an international reference pricing policy on total hospital drug spending.

Instead, we employ 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.

However, we might still be concerned that cost shifters or Hausman style instruments only weakly correlate with marginal cost, leading to a weak instrument problem. There are a number of reasons why marginal costs and prices may not covary as much as they do in other industries. First, markups can be very high in the pharmaceutical industry, so changes in the level of marginal costs may not correspond to meaningful changes in prices. Second, since drug prices are usually set through some form of bargaining—either between pharmaceutical companies and the government or between pharmaceutical companies and insurers—prices may be less responsive or slower to respond to marginal cost changes. For example, drug prices may not be renegotiated sufficiently frequently to respond to marginal cost variation, price increases may be explicitly prohibited by negotiated contracts, or prices may be tied to benchmarks (other countries' prices, value contribution, etc.) that lag or weaken prices' correlation with marginal costs. In addition to checking the power of instrumental variables in a first stage regression, we use alternative instruments based on the variation in competitive pressures as employed by Berry et al. (1995). BLP instrument validity is premised on the belief 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. Although we are not able to observe many characteristics of drugs whose variation may shift prices through the competitive channel, we nevertheless observe whether a drug is protected by a patent, the number of drugs within each therapeutic class, and the number of generics available (both in the class and for that particular drug). There is variation in these variables over time in each market because drugs may lose their patent protection and both brands and generics may enter or exit the market. Furthermore, since patent protection is determined long in advance and entry decisions can take years, it is unlikely that any of these instruments will correlate with the idiosyncratic demand shocks ξ_{jt}. As such, these variables satisfy the necessary conditions to help us identify price effects. 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.

3.3 Empirical Results on Demand Estimation

Before turning to the estimation, 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. We approximate the aggregate yearly market size denoted by M_{mt} for ATC-4 market m using a demand model that imposes zero variance of random coefficients—in which case it becomes a fixed coefficient logit—and a nonlinear least squares calibration procedure similar to that in Huang and Rojas (2013, 2014). This method estimates the market size as the solution to the maximization of a model fit that does not specify the outside option but uses market shares relative to one inside good instead (details of the method are in Appendix 7.2.1). On average, we find that the estimated outside market share is 29% in Canada and 24% in the US with some variation across ATC-4 classes (see detailed estimates in Appendix 7.2.2).

Table 3.1: *Demand Estimates for US and Canada*

Country		US		Canada	
Log Price	α	-2.254	(0.146)	-2.241	(0.206)
	σ^{α}	0.024	(0.246)	0.892	(0.224)
Generic Dummy	σ^{β}	1.628	(0.169)	0.357	(1.195)
Constant	σ^{γ}	0.042	(1.103)	1.562	(0.312)
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. All dummy coefficients are not reported.

Table 3.1 shows the estimation results by GMM for the demand model for the US and Canada. As explained before, we have a random coefficient on the log price variable which is normally distributed with a negative mean and a standard deviation that shows substantial heterogeneity in Canada (sufficiently small for the price coefficient to be distributed mostly in the negatives). The generic dummy random coefficient shows substantial heterogeneity in the US. In contrast, in Canada, much of the heterogeneity in demand is captured in the constant term and is thus common to all drugs. The demand model also has many molecule fixed effects, ATC-4 specific year effects, and ATC-4 specific off-patent and generic effects.

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

	US		Canada	
	Own	Cross	Own	Cross
All	-2.033	0.124	-2.017	0.158
Branded	-2.044	0.155	-1.809	0.185
Generic	-2.021	0.147	-2.262	0.163

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

Using these demand estimates, we can compute the price elasticities of the aggregate demand by ATC-4 market and quarter. Table 3.2 presents the average own and cross price elasticities across all these markets. This shows slightly higher price elasticities for generics in Canada than in the US and than branded drugs in Canada.

4 Supply Side Modeling and Estimates

4.1 Price setting with Bargaining

In the context of price regulated pharmaceutical markets such as Canada (and it would be similar in most European countries), we model firms and government behaviors in the price setting of pharmaceuticals using a bargaining model where firms want to maximize profits and the government wants to maximize consumer welfare. As there is no international reference pricing, there is no need to introduce a country index and pricing is determined independently across countries.

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

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

where c_{jt} and p_{jmt} are marginal costs and prices, respectively, q_{jt} is the total quantity (where $q_{jt} = M_{mt} s_{jt}$) and $\mathbf{p}_{mt} = (p_{1t}, .., p_{J_m t})$ is the vector of prices in market m at time t. The firm f profit across markets is then:

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

On the government side, we assume that the regulator's objective function depends on the consumers' welfare as revealed by the demand model and can be written for market m at period t as (Small and Rosen, 1981):

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

We assume that the firms and the government bargain product-by-product and do not bargain jointly over their portfolio of pharmaceutical drugs with a country. Then, at each time t and in each market m, prices are set product-by-product via Nash bargaining between the producer and the market m regulator, in order to maximize:

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

where $\Delta_j W_{mt}(p_{jt},\mathbf{p}_{-jmt})$ is the change in consumer welfare due to the presence of drug j in market mt :

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

where $\mathbf{p}_{-jmt}$ denotes the vector of all other than j prices in market m and period t and

$$W_{mt}(\infty,\mathbf{p}_{-jmt}) \equiv M_{mt}\int \ln\left[1+\sum\nolimits_{k\neq j}\exp\left(u_{ikt}\right)\right]dF(\nu_{im};\theta)$$

is the welfare in market mt when drug j is absent. And

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

as, for simplicity, we do not take into account the fact that a few multiproduct firms with an ATC-4 level market may take into account the substitution across their own portfolio of drugs. Note that the bargaining parameter $\rho_{jm}\in[0,1]$ is allowed to vary not only across ATC-4 markets but also across drugs. Specifically, we allow them to be different for on-patent drugs, branded off-patent drugs and generic drugs.

We assume a Nash-in-Nash equilibrium, which implies that the prices in the vector $\mathbf{p}_{-jmt}$ in case of disagreement are assumed to be equal to the equilibrium prices. Then, for all $j=1,..,J_m$ we have:

$$p_{jt} = \arg\max_{p_{jt}} \quad \left\{\Pi_{jmt}(p_{jt},\mathbf{p}_{-jmt})^{\rho_{jm}}\left(\Delta_j W_{mt}(p_{jt},\mathbf{p}_{-jmt})\right)^{1-\rho_{jm}}\right\} \tag{4.1}$$

Here, we assume that regulation of pharmaceutical prices in Canada makes unilateral price setting by firms impossible and that a bargaining model (similar to (Crawford and Yurukoglu, 2012; Grennan, 2013; Gowrisankaran et al., 2015; Ho and Lee, 2017)) is more likely to represent the way prices are determined as the Canadian government negotiates prices with manufacturers on behalf of its citizens. This is also true in most European countries.

Note that modeling prices as being set through Nash bargaining provides a parsimonious way to model the regulator's problem that balances the producer profits against consumer welfare. In Canada, we can interpret the bargaining literally since the Canadian Patented Medicine Prices Review Board negotiates prices with drug manufacturers to ensure that they are not "excessive".

The parameter ρ_{jm} represents the degree to which policy-makers in market m weight firm profits against immediate consumer welfare.

The necessary first-order conditions of the Nash bargaining equilibrium (4.1) imply that for all $j = 1, .., J_m$:

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

where

$$\frac{\partial \Delta_j W_{mt}\left(\mathbf{p}_{mt}\right)}{\partial p_{jt}} = \frac{\partial W_{mt}\left(\mathbf{p}_{mt}\right)}{\partial p_{jt}} = M_{mt} \int \frac{\partial W_{imt}\left(\mathbf{p}_{mt}\right)}{\partial p_{jt}} dF(\nu_{im};\theta) = M_{mt} \int s_{ijt} \frac{\partial u_{ijt}}{\partial p_{jt}} dF(\nu_{im};\theta) \tag{4.2}$$

Note that when $\rho_{jm} = 1$, so that pricing is set according to an unrestricted Bertrand-Nash equilibrium in prices where firms maximize profits and (4.1) simplifies to the usual condition:

$$c_{jt} = p_{jt} + \frac{q_{jt}\left(\mathbf{p}_{mt}\right)}{\partial q_{jt}\left(\mathbf{p}_{mt}\right) / \partial p_{jt}} \tag{4.3}$$

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 $p_{jt} = c_{jt}$.

4.2 Supply Side Parameters Identification and Estimation

The set of first-order conditions (4.1) 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.[10] In that case, the first-order conditions simplify to the usual Bertrand-Nash first-order conditions (4.3) 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, we impose that prices equal to marginal costs and do not estimate margins, which is

[10]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.

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 (4.1). Without any restriction on marginal costs, we cannot identify marginal costs and bargaining parameters. 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). 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:

$$c_{jt}\left(\rho_{jm(j)}\right) = z_{jt}'\lambda + \omega_{jt} \tag{4.4}$$

with

$$\mathbb{E}\left[z_{jt}\omega_{jt}\right] = 0 \qquad \forall j,t \tag{4.5}$$

and where $c_{jt}\left(\rho_{jm(j)}\right)$ is solution of (4.1). In our application, z_{jt} include a molecule-specific and country-time-specific effect.

The orthogonality conditions (4.5) allow to define for any market m in Canada and all j such that $m(j) = m$:

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

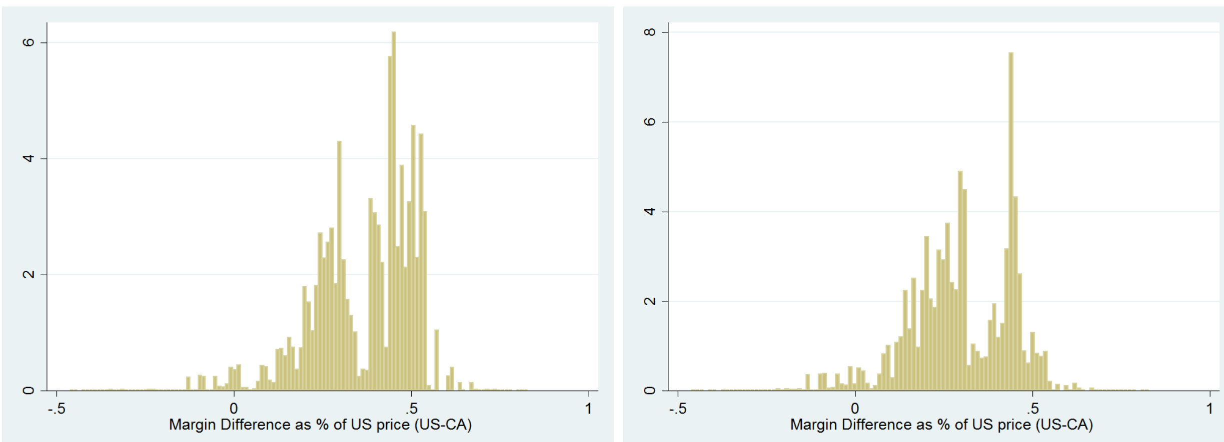
We have further identification power by leveraging our assumption that pricing is known to be set through an unconstrained Bertrand-Nash pricing game for all products sold in the US (excluding Federal sales). Thus, introducing the US index (no country index means Canada) we solve for any ATC-4 class m in Canada:

$$\rho_{jm} = \arg\min_{\rho_{jm}} \left[\sum\nolimits_{j,t} \omega_{jt}^2\left(\rho_{jm}\right) + \sum\nolimits_{j,t} \omega_{jUSt}^2\right] \tag{4.6}$$

where ω_{jUSt} is the residual of the equivalent cost equation (4.4) in the US using estimated c_{jUSt} from (4.3).

Table 7.3 in Appendix 7.3 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 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 dollars 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 distribution 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 7.4 in Appendix 7.3. The parameters vary between 0 and 1.

5 Counterfactual Policies

Our structural model allows us to evaluate several counterfactual policies of interest. We first define the counterfactual equilibrium and then present empirical estimates of these counterfactuals.

5.1 Counterfactual Equilibrium Definition

First, we consider a counterfactual in which the US enforces a price parity policy in reference to Canada. This type of policy is often referred to as an 'international reference pricing' policy, or a 'most favored nation' clause. Generally, the goal of such a policy is for the US to insist on paying the lowest price offered in other markets. The equilibrium effects of this policy could have drastic implications for consumers both in the US and in the referenced country.

A key feature of reference pricing is the interdependence of prices between different markets. Whereas if the US were to negotiate for drug prices without reference, the prices it would achieve would only impact US consumers to a first-order approximation (without taking into account innovation considerations), reference pricing links US pricing to negotiations abroad. A net benefit for US consumer welfare may result in a net loss for Canadian consumers. Similarly, a loss in pharmaceutical profits in the US market may correspond to a gain in pharmaceutical profits abroad. Both of these effects are theoretically ambiguous. As pricing is constrained by bargaining in Canada, the international reference pricing rule in the US may aid firms in negotiations with Canada. The effects of such a rule would depend on the way that it is implemented and enforced in the US.

We consider two main forms of implementation. The first form of reference pricing can be thought of as forcing Canadian prices to act as *'price ceilings'* for US prices. The second form can be thought of making US prices operate as *'price floors'* for Canadian prices. These two interpretations correspond to whether firms can commit to prices in the US before negotiating with Canada.

First, consider the case that Canadian prices are treated as *'price ceilings'* for the US. The US government enforces a rule that it will not allow firms to sell in the US at a higher price than in Canada. In this case, when negotiating over prices with Canada, firms must take into account the fact that they will not be able to price at a higher level in the US. As such, the US government commits not to allow firms to sell in the US at a higher price than in Canada, even if there exists a consumer (patient) welfare improving price above the Canadian price. Consequently, firms must raise the Canadian price or decrease the US price (or both) in order to sell their drugs in the US.

Second, consider the case that US prices act as *'price floors'* for Canadian prices. If firms are able to commit to a US price floor before negotiating prices in Canada and if this commitment is not renegotiable after setting prices in Canada, then the chosen price would affect the price negotiations in Canada in a way that may be favorable to pharmaceutical firms, as well as to the US government. Of course, such a policy requires strong commitment as it requires that firms will not lower prices than the initially agreed price floor in the US. As we will show, such commitment is credible, as it could be beneficial for the US consumers.

5.1.1 International Reference Pricing without Ex Ante Commitment

Suppose that the US implements a reference pricing policy such that the price of a drug in the US cannot be higher than the price of the same drug in Canada. Removing the time subscript, and introducing a US index (while no index means Canada), we assume that for drug j, it must be that:

$$p_{jUS} \leq p_j.$$

The equilibrium prices are those that would prevail in the US and Canada under this constraint and the bargaining regulation described above. We first consider the case without ex ante commitment by the US government, such that even if pharmaceutical firms choose prices in the US first, they cannot commit not to decrease prices in the US after negotiating with the Canadian regulator—even if that is profitable. Thus, negotiations between the firm and the Canadian regulator account for the impact that the price p_j has on US profits through the US price p_{jUS} and the constraint $p_{jUS} \leq p_j$. We can think of the negotiated p_j as affecting the choice set for p_{jUS}. Note that since p_{jUS} is chosen unilaterally without observing negotiated prices in Canada and firms negotiate simultaneously in Canada, the game in which p_j is chosen before p_{jUS} and the game in which p_j and p_{jUS} are chosen simultaneously are strategically equivalent. For simplicity of exposition, we consider the firms as sequentially negotiating p_j prior to setting p_{jUS}.

Thus, firm j and the Canadian regulator bargain over p_j for market m in order to maximize the Nash product:

$$\left(\underbrace{\Pi_j(p_j, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS})}_{\text{total profit for } j \text{ if agrees in } m} - \underbrace{\Pi_{jUS}(p_{jUS}(\infty, \mathbf{p}_{-jUS}), \mathbf{p}_{-jUS})}_{\text{profit of } j \text{ in US only if not in } m}\right)^{\rho_{jm}} \left(\underbrace{\Delta_j W_m(p_j, \mathbf{p}_{-jm})}_{\text{welfare gain in } m \text{ if agrees}}\right)^{1-\rho_{jm}}$$

where $\Pi_{jUS}(p_{jUS}(\infty, \mathbf{p}_{-jUS}), \mathbf{p}_{-jUS})$ is the profit of firm j in the US if it disagrees in m (we set $p_j = \infty$ by convention)[11], $\mathbf{p}_{-jUS}$ denotes the vector of all other US prices than j in ATC-4 class $m(j)$, $\mathbf{p}_{-jm}$ denotes the vector of all other Canadian prices than j in ATC-4 class $m = m(j)$ and $\Pi_j(p_j, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS})$ is the firm j's profit in case of agreement in m and defined as:

$$\Pi_j(p_j, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS}) \equiv \underbrace{\Pi_{jUS}(p_{jUS}(p_j, \mathbf{p}_{-jUS}), \mathbf{p}_{-jUS})}_{\text{profit of } j \text{ in the US if present}} \mathbf{1}_{\{p_j \geq p_{jUS}(p_j, \mathbf{p}_{-jUS})\}} + \underbrace{\Pi_{jm}(p_j, \mathbf{p}_{-jm})}_{\text{profit of } j \text{ in } m}.$$

Here, $\Pi_{jUS}(p_{jUS}(p_j, \mathbf{p}_{-jUS}), \mathbf{p}_{-jUS})$ is the profit of j in the US if firm j chooses to participate in the US market by setting $p_{jUS} \leq p_j$. Similarly, $\Pi_{jm}(p_j, \mathbf{p}_{-jm})$ is the profit in m. If firm j elects not to sell in the US (i.e., $p_{jUS} = \infty$), then the total product j profit is $\Pi_{jm}(p_j, \mathbf{p}_{-jm})$.

[11]While unlikely, this is possible if the market m is large, price sensitive, and has low marginal cost, while the equivalent ATC-4 class in the US would be small, price sensitive, and with high marginal cost.

Note that in the negotiation of price p_j in market m, p_{jUS} is taken to maximize firm j's profit in the US given p_j and $\mathbf{p}_{-jUS}$. Formally, it is defined by:[12]

$$p_{jUS}(p_j, \mathbf{p}_{-jUS}) \equiv \arg \max_{p \in [0, p_j] \cup \{\infty\}} \Pi_{jUS}\left(p, \mathbf{p}_{-jUS}\right) \mathbf{1}_{\{p_j \geq p_{jUS}\}}.$$

As negotiations in market m are private, and take place prior to the marketing and sales of drugs in the US, firms do not observe their competitors' prices in the US while negotiating and the Nash equilibrium is thus such that $\left(\mathbf{p}^*_{jUS}, \mathbf{p}^*_{jm}\right) = \left(p^*_{jUS}, \mathbf{p}^*_{-jUS}, p^*_j, \mathbf{p}^*_{-jm}\right)$ satisfy:

$$\begin{cases} p^*_j & = \arg\max_{p_j} \left(\Pi_j(p_{jUS}(p_j, \mathbf{p}^*_{-jUS}), \mathbf{p}^*_{-jUS}) - \Pi_{jUS}(p_{jUS}(\infty, \mathbf{p}^*_{-jUS}), \mathbf{p}^*_{-jUS})\right)^{\rho_{jm}} \left(\Delta_j W_m(p_j, \mathbf{p}^*_{-jm})\right)^{1-\rho_{jm}} \\ p^*_{jUS} & = \arg\max_{p_{jUS} \in [0, p^*_j] \cup \{\infty\}} \Pi_{jUS}\left(p_{jUS}, \mathbf{p}^*_{-jUS}\right) \end{cases}$$

In appendix 7.4, we develop a detailed description of the optimization algorithm that we use to solve for this counterfactual equilibrium.

5.1.2 International Reference Pricing with Ex Ante Commitment

Suppose that firms set prices in the US, taking into account the effect that these prices will have on price negotiations in market m, and can commit not to change the proposed price in the US. We then assume that there is ex ante full commitment from the pharmaceutical company not to decrease the price in the US after negotiating with Canada. Moreover, negotiations in a Canadian market m are private, and take place prior to the marketing and sales of drugs in the US. As such, firms do not observe their competitors' prices in the US while negotiating in market the Canadian market m.[13]

The negotiations game operates as follows: firm j commits to a US price of p_{jUS} before negotiating the price p_j with the Canadian government. In particular, p_{jUS} cannot decrease as a result of negotiations in m because commitment acts as a price floor. Simultaneously, each firm $-j$ chooses prices $\mathbf{p}_{-jUS}$ and $\mathbf{p}_{-jm}$ in an analogous way, and only observes p_j and p_{jUS} after firm j has determined both prices. In this game, we consider the policy in which the US administration commits to only allowing the sale of drug j if the US price is the lowest that the firm offers, i.e. $p_{jUS} \leq p_j$. Thus, firm j bargains over price p_j under the constraint that it will only be able to sell in the US if $p_{jUS} \leq p_j$. If, instead, firm j chooses a price $p_j < p_{jUS}$ then it will be forced to abandon the US market and lose its market share in the US entirely.

[12]The firm chooses not to participate in the US market if $p_{jUS}(p_j, \mathbf{p}_{-jUS}) > p_j$.

[13]In addition to enforcing that all negotiation occurs prior to marketing and sales, we are also assuming that US prices are unverifiable to firms so that the m government cannot credibly communicate competitors' US prices to firms during negotiations.

In such a case, firm j and the Canadian regulator of market m bargain over p_j in order to maximize:

$$\left(\underbrace{\Pi_{jUS}(p_{jUS}, \mathbf{p}_{-jUS})\mathbf{1}_{\{p_j \geq p_{jUS}\}} + \Pi_{jm}(p_j, \mathbf{p}_{-jm})}_{\text{total profit of } j \text{ if agrees in } m} - \underbrace{\Pi_{jUS}(p_{jUS}, \mathbf{p}_{-jUS})}_{\text{profit of } j \text{ if only in the US}}\right)^{\rho_{jm}} \left(\underbrace{\Delta_j W_m(p_j, \mathbf{p}_{-jm})}_{\text{welfare gain in } m \text{ if agrees}}\right)^{1-\rho_{jm}}$$

where $\Pi_{jUS}(p_{jUS}, \mathbf{p}_{-jUS})\mathbf{1}_{\{p_j \geq p_{jUS}\}} + \Pi_{jm}(p_j, \mathbf{p}_{-jm})$ is the total profit of j if it agrees on a price p_j.

As the solution of this bargaining for j, $p_j(p_{jUS}, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS})$ is a function of p_{jUS}, $\mathbf{p}_{-jm}$, and $\mathbf{p}_{-jUS}$, firm j anticipates bargaining with the Canadian government when choosing the US price. Thus p_{jUS} is chosen as:

$$\max_{p_{jUS}} \quad \Pi_{jUS}\left(p_{jUS}, \mathbf{p}_{-jUS}\right) + \Pi_{jm}(p_j\left(p_{jUS}, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS}\right), \mathbf{p}_{-jm})$$

Thus, the Nash equilibrium $\left(\mathbf{p}^*_{jUS}, \mathbf{p}^*_{jm}\right) = \left(p^*_{jUS}, \mathbf{p}^*_{-jUS}, p^*_j, \mathbf{p}^*_{-jm}\right)$ must satisfy:[14]

$$\begin{cases} p^*_{jUS} & = \underset{p_{jUS}}{\arg\max} \quad \Pi_{jUS}\left(p_{jUS}, \mathbf{p}^*_{-jUS}\right) + \Pi_{jm}(p_j\left(p_{jUS}, \mathbf{p}^*_{-jm}, \mathbf{p}^*_{-jUS}\right), \mathbf{p}^*_{-jm}) \\ p^*_j & = p_j\left(p^*_{jUS}, \mathbf{p}^*_{-jm}, \mathbf{p}^*_{-jUS}\right) \end{cases}$$

Appendix 7.4 presents the detailed algorithm that we use to solve for this counterfactual equilibrium.

5.2 Simulation Results

Using our estimates of the demand and supply side models presented in sections 3 and 4, we simulate the effects of the counterfactual pricing policy in the US on both the US and Canadian market, by therapeutic class. We assume that the policy applies only to drugs still protected by a patent because generics or branded off-patent drugs have much less price variation across countries and are also less expensive.

When looking at the price equilibrium, we take into account the full set of available drugs, including generics and branded off-patent drugs, since they also affect the equilibrium. Given that the reference pricing policy is relevant only when a given on-patent molecule is sold in both the US and Canada within a given ATC-4 therapeutic class, we use the ATC-4 classes that we describe in Table 2.1.

[14]Note that it is also possible that j may not want to participate in the US market. We additionally allow the firm to exit the US market when the following participation constraint does not hold:
$\underset{p_{jUS}}{\arg\max} \quad \Pi_{jUS}\left(p_{jUS}, \mathbf{p}_{-jUS}\right) + \Pi_{jm}(p_j\left(p_{jUS}, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS}\right), \mathbf{p}_{-jm}) \geq \Pi_{jm}(p_j\left(\infty, \mathbf{p}_{-jm}, \mathbf{p}_{-jUS}\right), \mathbf{p}_{-jm})$.

5.2.1 International Reference Pricing without Ex Ante Commitment

We first look at the results of the counterfactual in which the US imposes an international reference pricing rule (or most favored nation clause) without ex ante commitment. In this case, the price of the same drug in Canada acts as a price ceiling in the US.

Table 5.1 shows the results on expenses by ATC-4 class. Overall, it shows that the new price equilibrium would lead to a very small decrease in expenses in the US, but a very large increase in Canada (Table 7.11 in appendix 7.5.1 presents the average prices by ATC-4 before and after the policy change). In most ATC-4 classes, the change in expenses in the US is small, but it is not always negative—meaning that for some markets, the policy can lead to an increase in expenditures in the US even if prices are slightly decreasing.

For example, for the important class of chemotherapy drugs L1C0, which represents more than 10% of expenses in Canada and more than 4% in the US before the policy change, the policy would lead to price increases in both countries. The effect in Canada is much larger, however, with a 13.7% price increase, while US prices increase by 3.2%. For the N5A1 class of antipsychotics, which represent 14.8% in the US and 13.1% in Canada, the policy would not make the US spend substantially less (only -0.5%) but would induce a massive increase in Canada with an 85.8% increase. The result of the policy would be similar for the L1X4 class of protein kinase inhibitor (an anticancer drug), as expenses would increase in Canada by almost 26.9% while staying almost identical in the US (-0.3%). The same is true for another important class, B1B2, which covers fractionated heparins (an anticoagulant). In total, expenses would increase by 52% in Canada but decrease only by 0.6% in the US. This policy thus does not appear to save very much in US expenditures. This effect is due in part to the size of the US market compared to Canada. However, this is not the only determinant. We discuss the effect of market size in section 5.3.

Table 7.5 in appendix 7.5.1 shows the changes in quantities (standard units) that would result from the international reference pricing policy. It shows that there would be a slight increase in the use of drugs in the US (due to slightly lower prices) and a larger decrease in Canada. This observation suggests that the welfare effects on Canadian consumers are potentially very negative.

In this counterfactual, there are four on-patent drugs from four ATC-4 classes that exit from the US market in the counterfactual (there is never exit from the Canadian market as it is always possible to raise the price sufficiently to satisfy the international reference pricing constraint). They represent small market shares and small amounts of expenses except for one product in the anti-rheumatics class M1A1, which combines Diclofenac with Misoprostol. This product represents 4.8% of average expenses in the class, and exits between 2008 and 2011.[15]

Table 5.1: *Counterfactual Expenses Changes on All Drugs with Canada as Price Ceiling for the US*

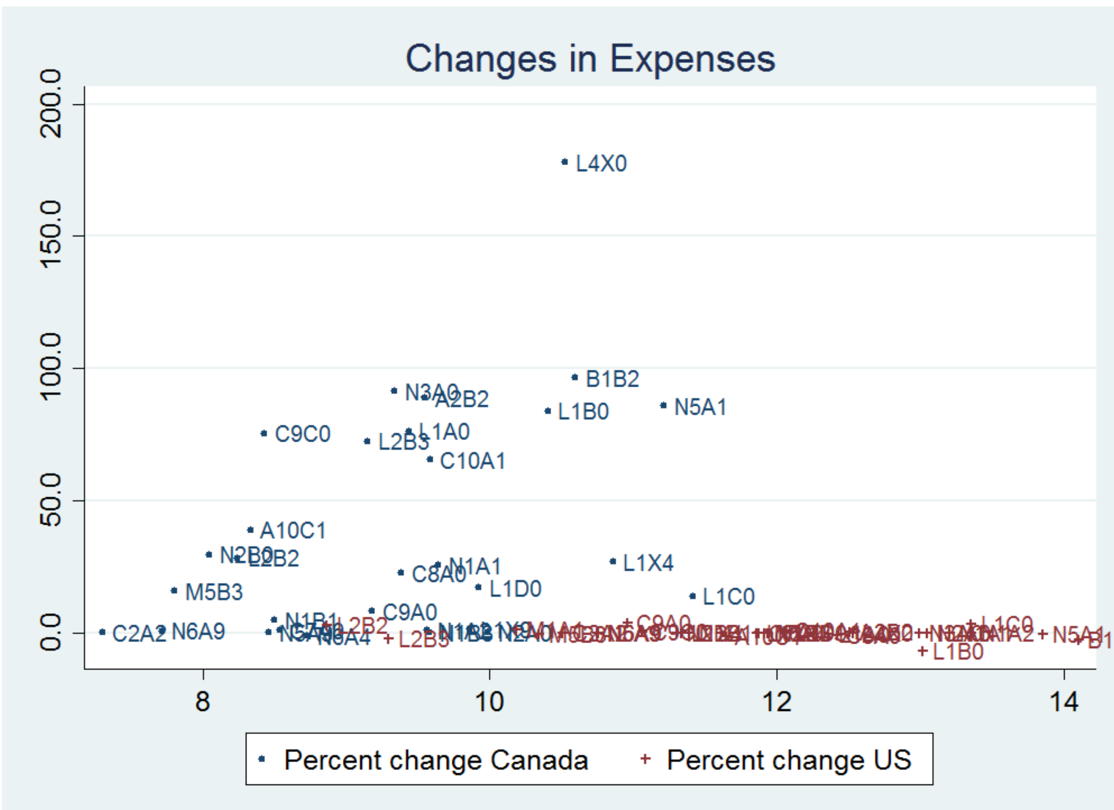
	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	0.62			4161	5777	38.8	113984	112471	-1.3
A2B2	0.55	0.90	0.87	14057	26529	88.7	270730	272016	0.5
B1B2	0.70			40084	78711	96.4	1326672	1292428	-2.6
C10A1	0.54	1.00	0.77	14549	24038	65.2	171667	172718	0.6
C2A2	1.00	1.00	0.94	1484	1484	-0.0	36579	36579	0.0
C7A0	0.72	1.00	1.00	5103	5144	0.8	143544	143553	0.0
C8A0	0.56	0.89	0.86	11908	14573	22.4	247149	245348	-0.7
C9A0	0.47	0.95	1.00	9728	10512	8.1	57229	59278	3.6
C9C0	0.60	0.94	0.50	4588	8040	75.2	63460	63616	0.2
L1A0	0.91	0.50	1.00	12525	22054	76.1	232379	231182	-0.5
L1B0	0.64	0.50	1.00	33075	60786	83.8	449600	418495	-6.9
L1C0	0.50	0.50	0.98	90792	103251	13.7	629957	649874	3.2
L1D0	0.99	0.50	0.50	20424	23867	16.9	171677	171784	0.1
L1X4	1.00	0.50	0.50	51978	65939	26.9	83862	83630	-0.3
L1X9	0.92	0.50	0.57	19173	19416	1.3	141652	141573	-0.1
L2B2	0.83	0.94	0.61	3808	4881	28.2	7079	7281	2.9
L2B3	0.70	0.79	0.58	9413	16216	72.3	10846	10606	-2.2
L4X0	0.95	0.91	1.00	37386	103864	177.8	275654	274975	-0.2
M1A1	0.44	0.91	1.00	1604	5179	223.0	26505	26865	1.4
M5B3	0.93	0.95	0.54	2455	2837	15.5	31052	30933	-0.4
N1A1	0.45	0.57	1.00	15417	19358	25.6	543474	541875	-0.3
N1A2	1.00	1.00	0.92	14275	14395	0.8	627990	628001	0.0
N1B1	0.96	1.00	0.75	4917	5142	4.6	88133	88144	0.0
N1B3	0.50	0.50	0.58	14496	14496	0.0	152988	152988	-0.0
N2A0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N2B0	0.50	0.96	0.88	3135	4058	29.4	81298	81300	0.0
N3A0	0.87	0.93	1.00	11366	21739	91.3	438695	439107	0.1
N5A1	0.86	0.86	0.94	74422	138244	85.8	1039056	1033974	-0.5
N5A9	0.64	0.97	0.94	4746	4746	0.0	46400	46398	-0.0
N6A4	0.80	0.99	0.91	6183	6110	-1.2	149528	149454	-0.0
N6A9	0.27	0.89	0.99	2245	2258	0.6	46742	46767	0.1
Total				561233	855382	52.4	8170027	8117658	-.6

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.

[15] The other drugs that exit are the ATC-4 classes A10C1, B1B2, and C9A0, and have expenditure shares between 0.1% and 1.5%

Figure 5.1 shows the average expenditure changes in percentages for Canada and the US against the log expenses for each ATC-4 class. The changes in the US are very small across drug classes. However, they are large in Canada in many cases, and appear even larger for the high-spending classes. ATC-4 classes such as anti-cancers: L4X0 (immunosuppressants), L1B0 (anti-metabolites), L1X4 (protein kinase inhibitors), L1A0 (alkylating agents) are important classes on which Canada spends much less than the US. These classes would experience large increases in expenditure after the implementation of an international reference pricing policy. Classes such as A2B2 (acid pump inhibitors), C10A1 (statins), N3A0 (anti-epileptics), N5A1 (anti-psychotics) or B1B2 (fractionated heparins) would face large price increases as well.

Figure 5.1: *Changes in expenses by ATC-4 in counterfactual against log expenses observed*



Note: Each point corresponds to one ATC-4 labeled with its code. Percentage changes on vertical axis (not drawing if change larger than 200%). Log expenses on horizontal axis. Both US and Canada on same graph.

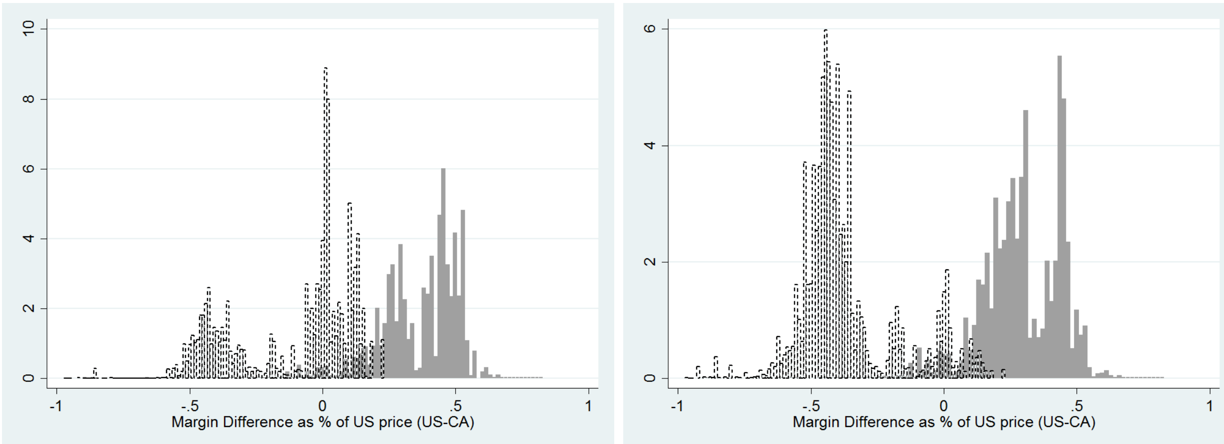
Table 7.6 in appendix 7.5.1 shows the changes in expenses, using only drugs that are on-patent. As with overall expenses, the US would save only 0.75% in overall expenses on these drugs, while Canadian expenditure would face an increase of 60.6%.

Table 7.7 in appendix 7.5.1 shows the average price changes that result from the international reference pricing policy, by ATC-4. It shows that the largest price changes are on patented drugs whose price increases by a large amount in Canada, but decreases to a smaller degree in the US.

Table 7.8 in appendix 7.5.1 shows the average prices for on-patent drugs in particular. It shows that for all classes, US prices decrease slightly, while Canadian prices increase to the level of the US prices or slightly higher.

Examining results at the drug level for on-patent drugs present in both countries, in particular, shows how international reference pricing affects margins by equalizing prices. As in the comparison of estimated margins between the US and Canada in Figure 4.1, we draw the distribution of counterfactual margins differences between the US and Canada. Figure 5.2 shows both the estimated and counterfactuals differences in margins for all on-patent drugs present in both countries, weighted either by US quantities or by Canadian quantities. This figure shows that the international reference pricing policy moves the distribution of margin differences to the left such that instead of having larger margins in the US than in Canada, the policy reverts this result. The left graph of Figure 5.2 shows that even weighting the distribution by the US quantities of each drug, a nonnegligible group of on-patent drugs will exhibit higher margins in Canada by an amount around 40% of the price of the drug. The right graph of Figure 5.2 shows that even weighting the distribution by the Canadian quantities of each drug, an even much larger amount of of on-patent drugs will exhibit higher margins in Canada. These graphs show that if the status quo margins are larger in the US, such that the distribution of differences is largely on the positive, then international reference pricing will not make the distribution of differences centered on zero,. Rather, margins will be higher in Canada for a substantial quantity of on-patent drugs. This occurs despite the fact that prices become close because marginal costs are typically higher in the US than in Canada. That is, international reference pricing policy makes prices more equal across countries but makes margins lower in the US and thus makes the US contribute less than Canada to pharmaceutical profits by unit of consumption.

Figure 5.2: *Counterfactual Margins Differences between US and Canada for on Patent Drugs*



Note: This distribution of margins differences by drug is weighted by the US quantities of the drug. This distribution is for the sample of on patent drugs present in both the US and Canada.

Table 5.2 shows the changes in profits by ATC-4 class and country. The table shows that profits in the US would decrease in total by 1.9% only, while they would increase in Canada by 65.6%. Table 7.9 in appendix 7.5.1 shows that consumer welfare would decrease overall in Canada by more than 12.3% while barely changing in the US (+0.2%). Finally, Table 7.10 in appendix 7.5.1 shows the overall effect, aggregating expenses, profits and welfare. This table shows that overall, total expenses in the US and Canada increase by 2.7%, that total profits increase by 5.1% and that consumer welfare decreases by 1%, as most of the changes occur in Canada, whose scale is much smaller than the US. Thus, an international reference pricing policy in the US has globally negative effects on the referenced country and is not able to substantially decrease either prices or expenses on drugs in the US.

Table 5.2: *Counterfactual Profits on All Drugs with Canada as Price Ceiling for the US*

ATC4	ρ_{jm} On Patent	Branded Off	Generic	Canada Before	Canada After	Canada Δ (%)	US Before	US After	US Δ (%)
A10C1	0.62			3147	5123	62.8	97767	95925	-1.9
A2B2	0.55	0.90	0.87	11212	23988	114.0	143282	142252	-0.7
B1B2	0.70			37401	75708	102.4	1279709	1243295	-2.8
C10A1	0.54	1.00	0.77	12037	21953	82.4	89953	88070	-2.1
C2A2	1.00	1.00	0.94	1439	1439	-0.0	4260	4260	0.0
C7A0	0.72	1.00	1.00	4853	4905	1.1	27738	27734	-0.0
C8A0	0.56	0.89	0.86	9790	12714	29.9	97479	96582	-0.9
C9A0	0.47	0.95	1.00	5921	7716	30.3	14233	13947	-2.0
C9C0	0.60	0.94	0.50	3139	6715	113.9	32509	31673	-2.6
L1A0	0.91	0.50	1.00	12000	21508	79.2	91496	90799	-0.8
L1B0	0.64	0.50	1.00	24193	51007	110.8	190112	170679	-10.2
L1C0	0.50	0.50	0.98	50263	72748	44.7	269879	265900	-1.5
L1D0	0.99	0.50	0.50	14564	17221	18.2	61282	61162	-0.2
L1X4	1.00	0.50	0.50	50602	64535	27.5	43552	43253	-0.7
L1X9	0.92	0.50	0.57	17276	17571	1.7	60304	60223	-0.1
L2B2	0.83	0.94	0.61	3468	4594	32.5	3503	3462	-1.2
L2B3	0.70	0.79	0.58	8559	15482	80.9	6585	5623	-14.6
L4X0	0.95	0.91	1.00	36855	102785	178.9	77871	77508	-0.5
M1A1	0.44	0.91	1.00	1319	4670	254.1	2592	2519	-2.8
M5B3	0.93	0.95	0.54	2151	2532	17.7	19601	19477	-0.6
N1A1	0.45	0.57	1.00	12530	16762	33.8	349549	347992	-0.4
N1A2	1.00	1.00	0.92	13656	13792	1.0	157280	157277	-0.0
N1B1	0.96	1.00	0.75	4678	4904	4.8	20696	20695	-0.0
N1B3	0.50	0.50	0.58	9221	9221	0.0	20075	20075	0.0
N2A0	0.51	0.78	0.89	19276	19278	0.0	45855	45855	0.0
N2B0	0.50	0.96	0.88	2984	3842	28.8	10947	10948	0.0
N3A0	0.87	0.93	1.00	10688	21015	96.6	116621	116554	-0.1
N5A1	0.86	0.86	0.94	69988	133776	91.1	526368	520215	-1.2
N5A9	0.64	0.97	0.94	3851	3852	0.0	3148	3147	-0.0
N6A4	0.80	0.99	0.91	5084	5371	5.6	70404	70171	-0.3
N6A9	0.27	0.89	0.99	1878	1913	1.9	13149	13123	-0.2
Total				464022	768639	65.59	3947799	3870395	-1.9

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_{jm} is the one estimated from the supply model in Canada and used for counterfactual simulations.

5.2.2 International Reference Pricing with Ex Ante Commitment

We now turn to the counterfactual with ex ante commitment in the US, such that the price in the US acts as a price floor in Canada. Table 5.3 shows the average changes in expenses across all

ATCs. Overall, the results of the previous counterfactual are similar or even reinforced. That is, prices increase substantially in Canada, do not change much in the US, and as a result expenses increase by 75.7% in Canada with a minimal change in the US (+0.5%). For most ATC-4 classes, expenses in the US would not change very much except for the anti-cancer class L2B3 (aromatase inhibitors) which is used for breast cancer. For this class, the predicted increase in expenses in Canada is especially large—nearly 300%, going from less than $9 million (USD) per year on average to more than $35 million. Note that without commitment, reference pricing results in a significantly smaller effect on L2B3 drugs. US expenses are predicted to decrease by only 0.6%, while Canadian expenses increase by 52.4%. This comparison shows that ex ante commitment can (in some cases) lead to much more important decreases in expenses in the US. For most classes, however, reference pricing results in small changes in expenses in the US. For classes in which expenses are very large in the status quo, such as the human insulin class B1B2, prices would increase by 3.3% (however, this represents more than $20 million per year). In Canada, we predict that expenses almost double for B1B2, with more than $19 million more per year.

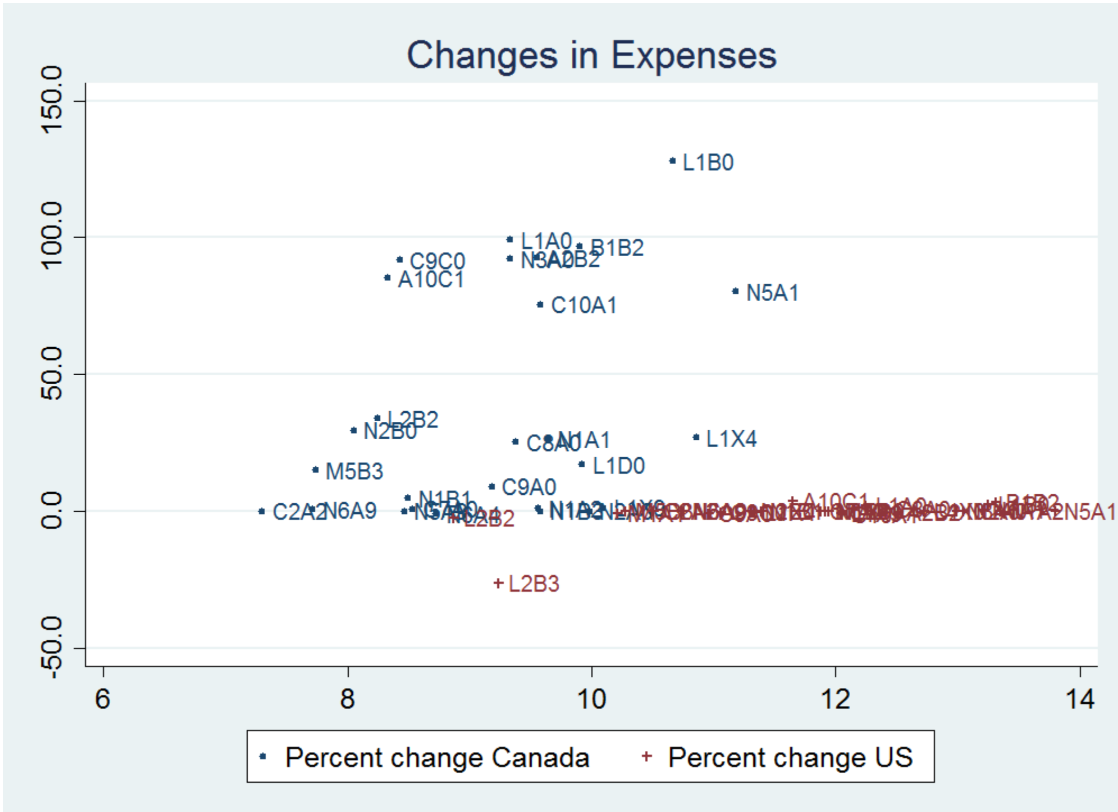
Table 5.3: *Counterfactual Expenses on All Drugs with US as Price Floor for Canada*

ATC4	ρ_{jm} On Patent	ρ_{jm} Branded Off	ρ_{jm} Generic	Canada Before	Canada After	Canada Δ (%)	US Before	US After	US Δ (%)
A10C1	0.62			4161	7698	85.0	114540	118714	3.6
A2B2	0.55	0.90	0.87	14057	27056	92.5	270730	269312	-0.5
B1B2	0.70			20119	39542	96.5	608073	628156	3.3
C10A1	0.54	1.00	0.77	14549	25521	75.4	171667	169878	-1.0
C2A2	1.00	1.00	0.94	1484	1484	-0.0	36579	36579	0.0
C7A0	0.72	1.00	1.00	5103	5145	0.8	143544	143550	0.0
C8A0	0.56	0.89	0.86	11908	14919	25.3	247149	249531	1.0
C9A0	0.47	0.95	1.00	9728	10597	8.9	57249	56767	-0.8
C9C0	0.60	0.94	0.50	4588	8787	91.5	63460	63159	-0.5
L1A0	0.91	0.50	1.00	11325	22521	98.9	208639	212718	2.0
L1B0	0.64	0.50	1.00	42957	97837	127.8	567516	581168	2.4
L1D0	0.99	0.50	0.50	20424	23871	16.9	171677	171769	0.1
L1X4	1.00	0.50	0.50	51978	65938	26.9	83862	83630	-0.3
L1X9	0.92	0.50	0.57	24379	24659	1.1	169878	168734	-0.7
L2B2	0.83	0.94	0.61	3808	5096	33.8	7079	6919	-2.3
L2B3	0.70	0.79	0.58	8961	35604	297.3	10302	7627	-26.0
L4X0	0.95	0.91	1.00	48328	158193	227.3	335879	336534	0.2
M1A1	0.44	0.91	1.00	1644	9314	466.6	27173	26976	-0.7
M5B3	0.93	0.95	0.54	2294	2637	15.0	28980	28980	-0.0
N1A1	0.45	0.57	1.00	15417	19477	26.3	543474	545239	0.3
N1A2	1.00	1.00	0.92	14275	14395	0.8	627990	628001	0.0
N1B1	0.96	1.00	0.75	4917	5143	4.6	88133	88118	-0.0
N1B3	0.50	0.50	0.58	14496	14496	0.0	152988	152988	-0.0
N2A0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N2B0	0.50	0.96	0.88	3135	4058	29.4	81298	81300	0.0
N3A0	0.87	0.93	1.00	11366	21817	91.9	438695	438541	-0.0
N5A1	0.86	0.86	0.94	72065	129771	80.1	982970	983222	0.0
N5A9	0.64	0.97	0.94	4746	4746	0.0	46400	46402	0.0
N6A4	0.80	0.99	0.91	6183	6108	-1.2	149528	149531	0.0
N6A9	0.27	0.89	0.99	2245	2259	0.6	46742	46743	0.0
Total				472376	830426	75.7	6946639	6985231	.5

Note: Expenses are average yearly expenses in 1,000 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.

Figure 5.3 shows the average changes of expenses in percentages by ATC-4 classes for Canada and the US, plotted against the log expenses of the class. We can see that the changes in US expenditure are very small across drug classes, with the exception of the L2B3 class. However, expenditure changes are large in Canada for many ATC-4 classes and appear even larger for the high-spending classes.

Figure 5.3: *Changes in expenses by ATC-4 in counterfactual against log expenses observed*

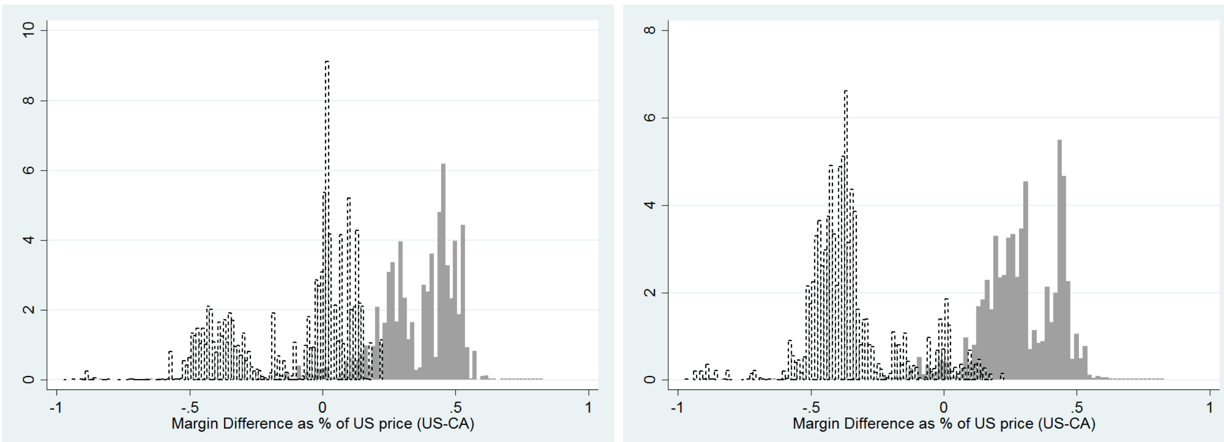


Note: Each point corresponds to one ATC-4 labeled with its code. Percentage changes areon the vertical axis (not drawing if change larger than 200%). Log expenses are on the horizontal axis. Both US and Canada are on the same graph.

Table 7.12 in appendix 7.5.2 shows the changes in quantities (standard units) that would result from reference pricing with ex-ante commitment. This table shows that there would be a slight decrease in the use of drugs in the US and a larger decrease in Canada. Table 7.13 in appendix 7.5.2 shows the changes in expenditure, using only on-patent drugs. On average, the US would spend 0.69% more in overall expenses on on-patent drugs, while Canada would have much larger expenditure increases: a 93.4% increase in the counterfactual with commitment, whereas the increase would be 60% ex ante commitment.

Table 7.14 in appendix 7.5.2 shows the average price changes by ATC-4. It shows that the largest price changes are for patented drugs with large price increases in Canada but smaller decreases in the US. Table 7.15 in appendix 7.5.2 shows the average prices for on-patents drugs only. Contrary to the case without ex ante commitment, US prices for these drugs do not (slightly) decrease due to the reference pricing policy, but stay the same or increase slightly for a few classes, while Canadian prices increase to the level of the US prices or slightly higher. As in the case without ex-ante commitment, we examine the results at the drug level. Figure 5.4 shows both the estimated and counterfactual differences in margins for all on-patent drugs present in both countries, weighted either by US quantities or by Canadian quantities. As in the case without commitment, this figure shows that the international reference pricing policy moves the distribution of differences in margins to the left such that instead of having larger margins in the US than in Canada, the policy causes margins to be higher in Canada than in the US.

Figure 5.4: *Counterfactual Margins Differences between US and Canada for on-Patent Drugs*



Note: This distribution of margins differences by drug is weighted by the US quantities of the drug. This distribution is for the sample of on patent drugs present in both the US and Canada.

Table 5.4 shows the changes in profits by ATC-4 class and country. It shows that firm profits in the US would increase in total by 1.4%, rather than decrease by 1.9% as in the case without ex-ante commitment. Profits in Canada would increase by 86.4%, instead of 65.6%. Table 7.16 in appendix 7.5.2 shows that consumer welfare would decrease overall in Canada by more than 13%, while it would barely change at all in the US (-0.2%).

Table 5.4: *Counterfactual Profits on All Drugs with US as Price Floor for Canada*

ATC4	ρ_{jm} On Patent	ρ_{jm} Branded Off	ρ_{jm} Generic	Canada Before	Canada After	Canada Δ (%)	US Before	US After	US Δ (%)
A10C1	0.62			3147	7058	124.2	98012	101680	3.7
A2B2	0.55	0.90	0.87	11212	24553	119.0	143282	143638	0.2
B1B2	0.70			18574	38591	107.8	571139	591894	3.6
C10A1	0.54	1.00	0.77	12037	23507	95.3	89953	91348	1.6
C2A2	1.00	1.00	0.94	1439	1439	-0.0	4260	4260	0.0
C7A0	0.72	1.00	1.00	4853	4906	1.1	27738	27742	0.0
C8A0	0.56	0.89	0.86	9790	13090	33.7	97479	98586	1.1
C9A0	0.47	0.95	1.00	5921	7911	33.6	14242	14253	0.1
C9C0	0.60	0.94	0.50	3139	7488	138.5	32509	33220	2.2
L1A0	0.91	0.50	1.00	10894	22071	102.6	80868	83130	2.8
L1B0	0.64	0.50	1.00	31298	82676	164.2	240837	251047	4.2
L1D0	0.99	0.50	0.50	14564	17224	18.3	61282	61180	-0.2
L1X4	1.00	0.50	0.50	50602	64534	27.5	43552	43253	-0.7
L1X9	0.92	0.50	0.57	22032	22439	1.8	73320	73467	0.2
L2B2	0.83	0.94	0.61	3468	4814	38.8	3503	3496	-0.2
L2B3	0.70	0.79	0.58	8140	35125	331.5	6206	5455	-12.1
L4X0	0.95	0.91	1.00	47554	156329	228.7	93069	93372	0.3
M1A1	0.44	0.91	1.00	1351	9012	566.8	2787	2741	-1.7
M5B3	0.93	0.95	0.54	1994	2335	17.1	17786	17785	-0.0
N1A1	0.45	0.57	1.00	12530	16897	34.9	349549	351515	0.6
N1A2	1.00	1.00	0.92	13656	13792	1.0	157280	157277	-0.0
N1B1	0.96	1.00	0.75	4678	4906	4.9	20696	20697	0.0
N1B3	0.50	0.50	0.58	9221	9221	0.0	20075	20075	0.0
N2A0	0.51	0.78	0.89	19276	19278	0.0	45855	45855	0.0
N2B0	0.50	0.96	0.88	2984	3842	28.8	10947	10948	0.0
N3A0	0.87	0.93	1.00	10688	21097	97.4	116621	116646	0.0
N5A1	0.86	0.86	0.94	67369	125091	85.7	478780	479551	0.2
N5A9	0.64	0.97	0.94	3851	3852	0.0	3148	3148	0.0
N6A4	0.80	0.99	0.91	5084	5372	5.7	70404	70433	0.0
N6A9	0.27	0.89	0.99	1878	1914	1.9	13149	13152	0.0
Total				413222	770361	86.40	2988326	3030844	1.4

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_{jm} is the one estimated from the supply model in Canada and used for counterfactual simulations.

5.3 International Reference Pricing Variants

As we have seen with the two sets of counterfactual simulations, the international reference pricing policy is likely to have small effects in most ATC-4 classes in the US, with a few notable exceptions. However, it would have generally very large effects in the reference country—in our case, Canada.

Our simulation results show that, in general, it would be too costly for pharmaceutical firms to decrease prices in the US. Rather, firms would respond to the policy by increasing prices in Canada—even if regulations in Canada can impose some downward pressure on price-setting in Canada. In the 31 ATC-4 classes of drugs, total spending in Canada is 472 million US$ on average annually, while it is 6,946 million US$ in the US. This difference is explained by both the fact that prices are much higher in the US than in Canada, and also because Canada is a much smaller country than the US in population.

Given these results, it is interesting to investigate some possible variants of the international reference pricing. One possible variant defines the reference pricing and Most Favored Nation clause using reference prices, but allows some fixed additional premium. Given that Canadian prices are much lower than in the US, one could consider that an international reference pricing rule with an additional 33% or 50% premium to the prices in Canada, for instance. Such a policy would be a priori less stringent on price-setting in the US and Canada, and could result both in a higher price decrease in the US and a lower price increase in Canada. Another policy variant might change the particular country being referenced and use a larger market. To simulate a counterfactual of this sort without re-estimating supply and demand, we simulate the international reference pricing policy in our main counterfactual section (without ex ante commitment—as if the Canadian prices are price ceilings for US prices) with a scaled up market size for Canada, such that it represents half of the US market, or is of the same size as the US market.

Table 5.5 shows the results of this counterfactual simulation for a subset of ATC-4 classes that each represent more than 3% of pharmaceutical expenditures in the US. We present the counterfactual expenses in the benchmark case (e.g. referencing Canadian prices), as well as for simulations with marked-up reference pricing (but keeping the Canadian market as is), and simulations with an inflated Canadian reference market (but the baseline reference pricing rule). In this table, the column“MFN", which takes values 0, 33 and 50, refers to simulations in which pricing in the US is referenced with respect to Canadian prices plus a markup of 0%, +33%, and +50% respectively. The column "Share US market", which takes values 0, 50 and 100, refers to simulations in which either the baseline Canadian market size (0), or a Canadian market size that is scaled up to represent 50% or being 100% of the US market, respectively.

We find that allowing for a +33% or +50% markup on reference prices in the US would lead to smaller price increases in Canada as well as similarly small changes in expenses in the US. Again, the simulations demonstrate that when the reference country's market size is relatively small, the reference pricing policy would mostly affect the referenced country, without benefiting the

US to a large degree. Moreover, our results show that increasing the market size of the referenced country to be comparable to the US—half of or comparable to the US market—implies greater reduction in the US price and a decrease in the Canadian price. Nonetheless, the asymmetry in effect size remains.

Table 7.19 in appendix 7.5.2 shows the results of the same simulations with international reference pricing with ex-ante commitment. As in our baseline case, these results generally show larger effects in magnitude when the firms and the US can commit ex-ante to a price floor that will constraint the reference country.

Table 5.5: *Counterfactual Expenses by ATC-4 with varying MFN rule (0, +33%, +50%) and Larger Reference Market (without ex ante commitment)*

			ρ_{jm}			Canada			US		
ATC4	MFN	US market Share	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A2B2	0	0	0.55	0.90	0.87	14057	26529	88.7	270730	272016	0.5
A2B2	0	50	0.55	0.90	0.87	87651	156990	79.1	263927	271068	2.7
A2B2	0	100	0.55	0.90	0.87	185358	311647	68.1	268488	278951	3.9
A2B2	33	0	0.55	0.90	0.87	14057	23928	70.2	270730	271609	0.3
A2B2	50	0	0.55	0.90	0.87	14057	22349	59.0	270730	271328	0.2
B1B2	0	0	0.70			40084	78711	96.4	1326672	1292428	-2.6
B1B2	0	50	0.70			273470	462709	69.2	1324179	1152193	-13.0
B1B2	0	100	0.70			485702	767729	58.1	1176227	930594	-20.9
B1B2	33	0	0.70			40084	62512	56.0	1326889	1310894	-1.2
B1B2	50	0	0.70			38563	50214	30.2	1284627	1277971	-0.5
L1B0	0	0	0.64	0.50	1.00	33075	60786	83.8	449600	418495	-6.9
L1B0	0	50	0.64	0.50	1.00	27299	52851	93.6	481761	459276	-4.7
L1B0	0	100	0.64	0.50	1.00	42581	74518	75.0	365435	337062	-7.8
L1B0	33	0	0.64	0.50	1.00	31638	54254	71.5	426957	404204	-5.3
L1B0	50	0	0.64	0.50	1.00	29628	45343	53.0	396918	381692	-3.8
N1A1	0	0	0.45	0.57	1.00	15417	19358	25.6	543474	541875	-0.3
N1A1	0	50	0.45	0.57	1.00	220806	267795	21.3	543474	520339	-4.3
N1A1	0	100	0.45	0.57	1.00	441612	523748	18.6	543474	503817	-7.3
N1A1	33	0	0.45	0.57	1.00	15417	16602	7.7	543474	543058	-0.1
N1A1	50	0	0.45	0.57	1.00	15417	15634	1.4	543474	543459	-0.0
N1A2	0	0	1.00	1.00	0.92	14275	14395	0.8	627990	628001	0.0
N1A2	0	50	1.00	1.00	0.92	65445	66059	0.9	627990	628042	0.0
N1A2	0	100	1.00	1.00	0.92	130890	132107	0.9	627990	628091	0.0
N1A2	33	0	1.00	1.00	0.92	14275	14354	0.6	627990	627998	0.0
N1A2	50	0	1.00	1.00	0.92	14275	14308	0.2	627990	627994	0.0
N2A0	0	0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N2A0	0	50	0.51	0.78	0.89	108392	108398	0.0	464444	464446	0.0
N2A0	0	100	0.51	0.78	0.89	216785	216799	0.0	464444	464448	0.0
N2A0	33	0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N2A0	50	0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N3A0	0	0	0.87	0.93	1.00	11366	21739	91.3	438695	439107	0.1
N3A0	0	50	0.87	0.93	1.00	70808	154260	117.9	438695	441048	0.5
N3A0	0	100	0.87	0.93	1.00	141617	305398	115.7	438695	442809	0.9
N3A0	33	0	0.87	0.93	1.00	11366	19879	74.9	438695	438915	0.1
N3A0	50	0	0.87	0.93	1.00	11366	17628	55.1	438695	438772	0.0
N5A1	0	0	0.86	0.86	0.94	74422	138244	85.8	1039056	1033974	-0.5
N5A1	0	50	0.86	0.86	0.94	104691	197505	88.7	1039056	1031817	-0.7
N5A1	0	100	0.86	0.86	0.94	212643	399326	87.8	1064367	1049939	-1.4
N5A1	33	0	0.86	0.86	0.94	74422	125483	68.6	1039056	1035314	-0.4
N5A1	50	0	0.86	0.86	0.94	74422	114947	54.5	1039056	1036307	-0.3

6 Conclusion

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. We develop two possible models of international reference pricing that differ according to which degree of ax ante commitment the international reference pricing can have. Without ex ante commitment of the international reference pricing rule in the US, the Canadian prices would serve as price ceilings for the same drugs sold in the US. With ex ante commitment, the US prices would serve as the price floor for the prices of the same drugs in Canada. In both cases, although with some slight and interesting variations across drug classes, 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 it 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. Overall, we find modest consumer welfare gains in the US, but substantial consumer welfare losses in Canada. Moreover, we find that pharmaceutical profits increase in net, suggesting that reference pricing of this form would constitute a net transfer from consumers to firms. Some variants of the simulations show that one would need a much larger reference market for this policy to have significant price reduction effects in the US.

References

Acemoglu, D., D. Cutler, A. Finkelstein, and J. Linn (2006). Did Medicare Induce Pharmaceutical Innovation. *American Economic Review, Papers and Proceedings*, 103–107.

Acemoglu, D. and J. Linn (2004). Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry. *The Quarterly Journal of Economics 119*(3), 1049–1090.

Berry, S. T., J. Levinsohn, and A. Pakes (1995). Automobile Prices in Market Equilibrium. *Econometrica 63*(4), 841–890.

Björnerstedt, J. and F. Verboven (2016). Does merger simulation work? Evidence from the swedish analgesics market. *American Economic Journal: Applied Economics 8*(3), 125–164.

Chaudhuri, S., P. K. Goldberg, and P. Jia (2006, dec). Estimating the Effects of Global Patent Protection in Pharmaceuticals: A Case Study of Quinolones in India. *American Economic Review 96*(5), 1477–1514.

Crawford, G. S. and A. Yurukoglu (2012, apr). The Welfare Effects of Bundling in Multichannel Television Markets. *American Economic Review 102*(2), 643–685.

Danzon, P. and L. Chao (2000a). Prices, competition and regulation in pharmaceuticals: a cross-national comparison.

Danzon, P. M. and L.-W. Chao (2000b). No Title. *Journal of Health Economics 19*(2), 159–195.

Danzon, P. M., Y. R. Wang, and L. Wang (2005). The impact of price regulation on the launch delay of new drugs - Evidence from twenty-five major markets in the 1990s. *Health Economics 14*(3), 269–292.

DiMasi, J. A., R. W. Hansen, and H. G. Grabowski (2003). The price of innovation: new estimates of drug development costs. *Journal of Health Economics 22*, 151–185.

DiMasi, J. A., R. W. Hansen, and H. G. Grabowski (2016). Innovation in the pharmaceutical industry: New estimates of R&D costs. *Journal of Health Economics 47*, 20–33.

DiMasi, J. A., R. W. Hansen William E Simon, H. G. Grabowski, and L. Lasagna (1991). Cost of innovation in the pharmaceutical industry*. Technical report.

Dubois, P., O. de Mouzon, F. Scott Morton, and P. Seabright (2015). Market size and pharmaceutical innovation. *The RAND Journal of Economics 46*(4), 844–871.

Dubois, P. and L. Lasio (2018). Identifying Industry Margins with Price Constraints: Structural Estimation on Pharmaceuticals. *American Economic Review forthcomin*.

European Pharmaceutical Market Research Association (2018). Anatomical Classification Guidelines V2018. Technical report.

Filson, D. (2012). A Markov-perfect equilibrium model of the impacts of price controls on the performance of the pharmaceutical industry. *RAND Journal of Economics 43*(1), 110–138.

Gowrisankaran, G., A. Nevo, and R. Town (2015, jan). Mergers When Prices Are Negotiated: Evidence from the Hospital Industry. *American Economic Review 105*(1), 172–203.

Gowrisankaran, G. and M. Rysman (2012, dec). Dynamics of Consumer Demand for New Durable Goods. *Journal of Political Economy 120*(6), 1173–1219.

Grennan, M. (2013, feb). Price Discrimination and Bargaining: Empirical Evidence from Medical Devices. *American Economic Review 103*(1), 145–177.

Grossman, G. M. and E. L. C. Lai (2004). International Protection of Intellectual Property. *94*(5), 1635–1653.

Helpman, E. (1993). Innovation, Imitiation, and Intellectual Property Rights. *Econometrica 61*(6), 1247–1280.

Ho, K. and R. Lee (2017). Insurer Competition in Health Care Markets. *Econometrica 85*(2), 379–417.

Horn, H. and A. Wolinsky (1988). Bilateral Monopolies and Incentives for Merger. *The RAND Journal of Economics 19*(3), 408.

Huang, D. and C. Rojas (2013). The Outside Good Bias in Logit Models of Demand with Aggregate Data. *Economics Bulletin 12*(1), 198–206.

Huang, D. and C. Rojas (2014). Eliminating the outside good bias in logit models of demand with aggregate data. *Review of Marketing Science 12*(1), 1–36.

Lakdawalla, D. N. (2018). Economics of the Pharmaceutical Industry. *Journal of Economic Literature 56*(2), 397–449.

Lakdawalla, D. N., D. P. Goldman, P. C. Michaud, N. Sood, R. Lempert, Z. Cong, H. De Vries, and I. Gutierrez (2009). U.S. pharmaceutical policy in a global marketplace. *Health Affairs 28*(1), 138–150.

Linnosmaa, I., R. Hermans, and T. Hallinen (2004). Price-cost margin in the pharmaceutical industry. Empirical evidence from Finland. *The European Journal of Health Economics 5*(2), 122–128.

Maini, L. and F. Pammoli (2017). Reference Pricing as a Deterrent to Entry: Evidence from the European Pharmaceutical Market.

Nevo, A. (2001). Measuring Market Power in the Ready-to-Eat Cereal Industry. *Econometrica 69*(2), 307–342.

OECD (2017). *Health at a Glance 2017 OECD InDICatOrs.*

Peters, B., M. J. Roberts, V. A. Vuong, and H. Fryges (2017, may). Estimating dynamic R&D choice: an analysis of costs and long-run benefits. *RAND Journal of Economics 48*(2), 409–437.

Salter, M. (2015). Reference Pricing: An Effective Model for the U.S. Pharmaceutical Industry? *Northwestern Journal of International Law & Business J. Int'l L. & Bus. Northwestern Journal of International Law & Business 35*(2).

Scott-Morton, F. (1997). The Strategic Response by Pharmaceutical Firms to the Medicaid Most- Favored-Customer Rules. *The RAND Journal of Economics 28*(2), 269.

Small, K. A. and H. S. Rosen (1981). Applied Welfare Economics with Discrete Choice Models. *Econometrica 49*(1), 105–130.

Weiss, J., P. Hakim, and R. Degun (2016). Impact of Implementing International Reference Pricing on Pharmaceutical Prices for United States Medicare. *Value in Health 19*(3), A89.

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
A10C1	H INSUL+ANG FAST ACT	12.05	37.13	12.05	37.13	0.00	0.00	0.00	0.00
A2B2	ACID PUMP INHIBITORS	0.76	2.44	0.83	2.75	0.67	3.43	0.59	0.63
B1B2	FRACTIONATED HEPARINS	15.65	37.61	15.65	38.01	0.00	30.42	0.00	28.47
C10A1	STATINS (HMG-COA RED	1.32	2.23	1.77	3.43	1.99	2.32	0.49	0.50
C2A2	ANTIHYPER.PL MAINLY PERI	0.60	1.35	46.08	13.16	2.79	2.09	0.16	1.06
C7A0	B-BLOCKING AGENTS,PLAIN	0.22	0.87	0.30	3.37	1.11	2.14	0.18	0.60
C8A0	CALCIUM ANTAGONIST PLAIN	0.93	3.40	1.30	2.32	0.83	25.38	0.49	1.17
C9A0	ACE INHIBITORS PLAIN	0.52	0.51	0.68	1.68	0.51	1.70	0.26	0.30
C9C0	ANGIOTEN-II ANTAG, PLAIN	0.97	2.31	1.10	2.72	1.19	2.64	0.25	0.47
L1A0	ALKYLATING AGENTS	17.69	135.17	24.69	229.55	1.53	109.79	14.51	48.55
L1B0	ANTIMETABOLITES	16.27	124.41	18.00	382.37	17.90	209.39	11.15	17.12
L1C0	VINCA ALKALOIDS	270.87	443.02	468.30	999.85	110.03	350.44	86.50	73.89
L1D0	ANTINEOPLAS. ANTIBIOTICS	164.08	322.95	250.68	1350.26	360.70	998.83	77.61	108.92
L1X4	A-NEO PROTEIN KINASE INH	66.23	112.85	66.35	112.77	65.16	0.00	25.55	146.05
L1X9	ALL OTH. ANTINEOPLASTICS	20.64	138.60	642.79	741.55	0.94	0.00	1.64	15.12
L2B2	CYTO ANTI-ANDROGENS	2.19	10.08	10.43	30.28	1.45	9.63	0.69	1.31
L2B3	CYTOSTAT AROMATASE INHIB	4.81	11.29	4.88	11.75	3.80	17.52	2.23	0.52
L4X0	OTHER IMMUNOSUPPRESSANTS	3.07	23.46	3.01	18.79	0.75	5.92	5.29	59.29
M1A1	ANTIRHEUMATICS NON-S PLN	0.19	0.27	0.67	3.68	0.50	0.95	0.13	0.23
M5B3	BISPHOSPH OSTEOPOROSIS	2.11	18.17	2.43	27.81	3.21	19.98	1.40	2.49
N1A1	INHAL GEN ANAESTHETICS	0.81	0.82	0.79	0.92	0.92	0.76	0.26	0.54
N1A2	INJECT GEN ANAESTHETICS	5.00	9.03	11.73	76.79	5.43	18.96	4.53	5.96
N1B1	ANAESTH LOCAL MEDIC INJ	4.48	4.35	10.97	15.64	4.63	6.76	3.19	2.84
N1B3	ANAESTH LOCAL TOPICAL	0.92	1.11	6.68	23.42	1.04	3.90	0.39	0.85
N2A0	NARCOTIC ANALGESICS	0.59	1.36	0.77	3.20	1.18	3.86	0.48	1.14
N2B0	NON-NARCOTIC ANALGESICS	0.31	0.53	0.56	14.59	0.34	1.34	0.30	0.39
N3A0	ANTI-EPILEPTICS	0.26	1.49	1.36	4.30	0.20	5.65	0.20	0.79
N5A1	ATYPICAL ANTIPSYCHOTICS	1.77	9.09	1.82	10.36	3.09	4.92	0.43	3.43
N5A9	CONVNTL ANTIPSYCHOTICS	0.46	1.27	2.90	2.76	1.17	16.30	0.25	1.11
N6A4	SSRI ANTIDEPRESSANTS	0.48	1.61	1.35	3.61	1.44	4.22	0.28	0.48
N6A9	ANTIDEPRESSANTS ALL OTH	0.19	0.63	0.40	2.95	0.58	3.47	0.13	0.32

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

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:

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

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

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

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 Estimates

7.3 Supply sides estimates

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

ATC4		s_{0mt} US	s_{0mt} Canada
A10C1	H INSUL+ANG FAST ACT	0.11	0.34
A2B2	ACID PUMP INHIBITORS	0.44	0.19
B1B2	FRACTIONATED HEPARINS	0.09	0.10
C10A1	STATINS (HMG-COA RED	0.27	0.10
C2A2	ANTIHYPER.PL MAINLY PERI	0.31	0.21
C7A0	B-BLOCKING AGENTS,PLAIN	0.10	0.25
C8A0	CALCIUM ANTAGONIST PLAIN	0.18	0.09
C9A0	ACE INHIBITORS PLAIN	0.65	0.60
C9C0	ANGIOTEN-II ANTAG, PLAIN	0.44	0.10
L1A0	ALKYLATING AGENTS	0.11	0.17
L1B0	ANTIMETABOLITES	0.13	0.27
L1C0	VINCA ALKALOIDS	0.59	0.39
L1D0	ANTINEOPLAS. ANTIBIOTICS	0.09	0.21
L1X4	A-NEO PROTEIN KINASE INH	0.17	0.54
L1X9	ALL OTH. ANTINEOPLASTICS	0.14	0.14
L2B2	CYTO ANTI-ANDROGENS	0.46	0.12
L2B3	CYTOSTAT AROMATASE INHIB	0.35	0.17
L4X0	OTHER IMMUNOSUPPRESSANTS	0.47	0.20
M1A1	ANTIRHEUMATICS NON-S PLN	0.12	0.14
M5B3	BISPHOSPH OSTEOPOROSIS	0.17	0.44
N1A1	INHAL GEN ANAESTHETICS	0.10	0.27
N1A2	INJECT GEN ANAESTHETICS	0.11	0.66
N1B1	ANAESTH LOCAL MEDIC INJ	0.10	0.26
N1B3	ANAESTH LOCAL TOPICAL	0.84	0.51
N2A0	NARCOTIC ANALGESICS	0.22	0.18
N2B0	NON-NARCOTIC ANALGESICS	0.09	0.09
N3A0	ANTI-EPILEPTICS	0.48	0.12
N5A1	ATYPICAL ANTIPSYCHOTICS	0.18	0.14
N5A9	CONVNTL ANTIPSYCHOTICS	0.19	0.63
N6A4	SSRI ANTIDEPRESSANTS	0.11	0.92
N6A9	ANTIDEPRESSANTS ALL OTH	0.21	0.39

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

Table 7.3: *Margins Estimates by ATC-4*

Margins		Canada				US		
ATC4	Label	All	On Patent	Branded Off Patent	Generics	All	On Patent	Branded Off Patent
A10C1	H INSUL+ANG FAST ACT	18.46	18.46			85.71	85.71	
A2B2	ACID PUMP INHIBITORS	37.81	38.58	28.47	83.87	54.04	53.87	63.67
B1B2	FRACTIONATED HEPARINS	38.61	40.25	0.00	0.00	96.56	96.95	100.00
C10A1	STATINS (HMG-COA RED	60.64	59.13	43.99	82.24	54.01	58.66	62.88
C2A2	ANTIHYPER.PL MAINLY PERI	49.10	96.35	96.62	16.52	11.30	37.65	11.83
C7A0	B-BLOCKING AGENTS,PLAIN	19.68	4.64	16.35	25.92	19.62	48.86	47.56
C8A0	CALCIUM ANTAGONIST PLAIN	25.12	73.56	10.69	21.73	39.46	66.31	45.52
C9A0	ACE INHIBITORS PLAIN	62.75	46.83	93.93	36.20	20.56	23.31	29.53
C9C0	ANGIOTEN-II ANTAG, PLAIN	47.54	44.63	96.05	43.82	51.47	53.49	10.64
L1A0	ALKYLATING AGENTS	11.69	13.03	1.41	10.95	39.69	47.46	46.62
L1B0	ANTIMETABOLITES	8.10	6.93	5.70	19.50	42.26	46.80	45.23
L1C0	VINCA ALKALOIDS	50.78	45.88	50.09	88.92	42.84	47.19	37.88
L1D0	ANTINEOPLAS. ANTIBIOTICS	31.08	45.37	20.93	25.08	35.24	46.35	49.96
L1X4	A-NEO PROTEIN KINASE INH	32.23	31.83	55.66	3.73	52.71	52.90	0.00
L1X9	ALL OTH. ANTINEOPLASTICS	13.40	14.06	76.78	3.61	42.34	46.55	0.00
L2B2	CYTO ANTI-ANDROGENS	35.18	29.57	50.79	77.99	49.43	54.39	48.54
L2B3	CYTOSTAT AROMATASE INHIB	50.67	50.58	29.19	73.32	63.92	64.26	47.59
L4X0	OTHER IMMUNOSUPPRESSANTS	19.66	33.59	0.65	2.73	28.20	47.87	48.10
M1A1	ANTIRHEUMATICS NON-S PLN	55.06	42.59	88.46	47.57	9.52	25.50	45.53
M5B3	BISPHOSPH OSTEOPOROSIS	6.78	4.27	17.31	27.39	57.62	62.06	48.38
N1A1	INHAL GEN ANAESTHETICS	62.35	41.64	94.54	17.15	64.71	73.89	45.85
N1A2	INJECT GEN ANAESTHETICS	20.27	13.40	16.56	24.06	25.12	47.01	58.07
N1B1	ANAESTH LOCAL MEDIC INJ	79.76	67.59	99.11	63.82	23.45	51.97	24.55
N1B3	ANAESTH LOCAL TOPICAL	68.36	47.28	71.38	28.14	5.34	1.82	6.54
N2A0	NARCOTIC ANALGESICS	40.15	49.76	47.88	37.55	10.30	11.35	46.03
N2B0	NON-NARCOTIC ANALGESICS	56.38	6.47	93.59	70.32	13.78	46.96	43.05
N3A0	ANTI-EPILEPTICS	29.69	20.77	23.32	40.51	25.82	45.45	44.93
N5A1	ATYPICAL ANTIPSYCHOTICS	18.67	9.06	92.70	20.99	50.42	53.94	4.12
N5A9	CONVNTL ANTIPSYCHOTICS	12.59	60.06	15.83	8.27	6.64	18.12	45.48
N6A4	SSRI ANTIDEPRESSANTS	2.35	1.37	2.15	6.29	46.86	58.64	47.95
N6A9	ANTIDEPRESSANTS ALL OTH	18.77	12.00	9.91	28.85	27.27	48.15	50.76

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 7.4: *Estimates of ρ_{jm} by ATC-4*

ATC4		On Patent	Branded Off	Generic
A10C1	H INSUL+ANG FAST ACT	0.62		
A2B2	ACID PUMP INHIBITORS	0.55	0.90	0.87
B1B2	FRACTIONATED HEPARINS	0.70		
C10A1	STATINS (HMG-COA RED	0.54	1.00	0.77
C2A2	ANTIHYPER.PL MAINLY PERI	1.00	1.00	0.94
C7A0	B-BLOCKING AGENTS,PLAIN	0.72	1.00	1.00
C8A0	CALCIUM ANTAGONIST PLAIN	0.56	0.89	0.86
C9A0	ACE INHIBITORS PLAIN	0.47	0.95	1.00
C9C0	ANGIOTEN-II ANTAG, PLAIN	0.60	0.94	0.50
L1A0	ALKYLATING AGENTS	0.91	0.50	1.00
L1B0	ANTIMETABOLITES	0.64	0.50	1.00
L1C0	VINCA ALKALOIDS	0.50	0.50	0.98
L1D0	ANTINEOPLAS. ANTIBIOTICS	0.99	0.50	0.50
L1X4	A-NEO PROTEIN KINASE INH	1.00	0.50	0.50
L1X9	ALL OTH. ANTINEOPLASTICS	0.92	0.50	0.57
L2B2	CYTO ANTI-ANDROGENS	0.83	0.94	0.61
L2B3	CYTOSTAT AROMATASE INHIB	0.70	0.79	0.58
L4X0	OTHER IMMUNOSUPPRESSANTS	0.95	0.91	1.00
M1A1	ANTIRHEUMATICS NON-S PLN	0.44	0.91	1.00
M5B3	BISPHOSPH OSTEOPOROSIS	0.93	0.95	0.54
N1A1	INHAL GEN ANAESTHETICS	0.45	0.57	1.00
N1A2	INJECT GEN ANAESTHETICS	1.00	1.00	0.92
N1B1	ANAESTH LOCAL MEDIC INJ	0.96	1.00	0.75
N1B3	ANAESTH LOCAL TOPICAL	0.50	0.50	0.58
N2A0	NARCOTIC ANALGESICS	0.51	0.78	0.89
N2B0	NON-NARCOTIC ANALGESICS	0.50	0.96	0.88
N3A0	ANTI-EPILEPTICS	0.87	0.93	1.00
N5A1	ATYPICAL ANTIPSYCHOTICS	0.86	0.86	0.94
N5A9	CONVNTL ANTIPSYCHOTICS	0.64	0.97	0.94
N6A4	SSRI ANTIDEPRESSANTS	0.80	0.99	0.91
N6A9	ANTIDEPRESSANTS ALL OTH	0.27	0.89	0.99

7.4 Algorithms for Computation of Counterfactuals

Our algorithm to compute the counterfactual consists in iterating applications of each firm's best response functions in a fixed random order to the current set of other firms' current best responses until the sum of the changes of all firms' prices is less than 0.1 cents. The only non-trivial best response functions to compute are those of on-patent products available in both the US and Canada. Our algorithm for computing these prices is as follows:

No Ex Ante Commitment:

1. Compute the firm's preferred price in the US if it were to consider the US market in isolation ($p_{j,US}^{unconst}$). The corresponding profit the firm receives in the US under this price is $\pi_{j,US}^{unconst}$, which is the disagreement profit the firm expects to receive if it exits the Canadian market.

2. Compute the Canadian price that would be set under Nash Bargaining with no pricing externality ($p_{j,CA}^{noext}$) - which happens if j exits the US.

3. Compute the Canadian price according to Nash Bargaining with Canada as follows:

   (a) Initialize our optimization from $p_{j,CA} = \max\{p_{j,US}^{unconst}, p_{j,CA}^{noext}) + .01$.

   (b) From single-peakedness of the Nash Bargaining objective function, if $p_{j,CA} < p_{j,US}^{unconst}$, then the firm either elects $p_{j,US} = p_{j,CA}$ or prefers to exit the US market.[16]

   - If $\pi_{j,US}(p_{j,US} = p_{j,CA}) < 0$, then the firm exits the US.
   - if $\pi_{j,US}(p_{j,US} = p_{j,CA}) \geq 0$, then $p_{j,US} = p_{j,CA}$.

   (c) If $p_{j,CA} \geq p_{j,US}^{unconst}$, then the firm prefers and can achieve $p_{j,US} = p_{j,US}^{unconst}$.

   (d) The firm never wishes to exit Canada because there always exists a sufficiently high price that the firm earns a profit in Canada, and the reference pricing rule does nothing to prohibit arbitrarily high Canadian prices. For $p_{j,CA}$ for which the firm prefers disagreement, we impose an infinite penalty on the objective in our optimization algorithm.

Ex Ante Commitment:

1. Compute the prices in the US and Canada if the firm considered each price independently: ($p_{j,US}^{unconst}$ and $p_{j,CA}^{noext}$).

2. Compute the prices in the case that the reference pricing constraint is binding: $p_{j,US}^{const} = p_{j,CA}^{const} = \arg\max_p\{\pi_{j,US}(p) + \pi_{j,CA}(p)\}$.[17]

3. The above assumes that the firm wishes to participate in both the US and Canadian markets when the constraint binds. We check whether the firm wishes to participate in the US even if constrained:

   - If the firm prefers to participate in the US even if constrained, i.e. $\pi_{j,US}(p_{j,US}^{const}) + \pi_{j,CA}(p_{j,CA}^{const} > \pi_{j,CA}(p_{j,CA}^{unconst})$, then we check whether the firm prefers constrained pricing over unconstrained pricing.

[16] We also validate single-peakedness by perturbing the equilibrium prices to ensure that the firm would not like to lower its US price below the Canadian price in such cases.

[17] We initialize our optimization with the maximum of the product's previous best response price for US and Canada.

- If the firm prefers constrained pricing to unconstrained pricing, then $p_{j,US} = p_{j,US}^{const}$ and $p_{j,CA} = p_{j,CA}^{const}$.
- If the firm prefers unconstrained pricing to constrained pricing, then we check whether the unconstrained pricing is feasible:
    * If the unconstrained pricing is feasible (i.e. satisfies the reference pricing rule), then $p_{j,US} = p_{j,US}^{unconst}$ and $p_{j,CA} = p_{j,CA}^{noext}$.
    * If unconstrained pricing is unfeasible, then $p_{j,US} = p_{j,US}^{const}$ and $p_{j,CA} = p_{j,CA}^{const}$.

- If the firm prefers not to participate in the US given the constraint, then we set $p_{j,US}^{const} = \infty$ and $p_{j,CA}^{const} = p_{j,CA}^{noext}$ and test whether the constrained prices are feasible.
    - If the unconstrained pricing is feasible (i.e. satisfies the reference pricing rule), then $p_{j,US} = p_{j,US}^{unconst}$ and $p_{j,CA} = p_{j,CA}^{noext}$.
    - If the unconstrained pricing is unfeasible, then the firm exits the US market, and $p_{j,CA} = p_{j,CA}^{noext}$.

The best responses for the off-patent molecules are described as follows:

- **US Generic products:** set $p_j = mc_j$ in the United States.
- **Canadian Generic products:** set price to according to Nash bargaining with parameter $\rho_{CA}^{generic}$ and other prices $\mathbf{p}_{-j,CA}$.
- **US Branded Off-Patent Drugs:** set price to according to Nash bargaining with parameter $\rho_{US}^{branded}$ and other prices $\mathbf{p}_{-j,US}$.
- **CA Branded Off-Patent Drugs:** set price to according to Nash bargaining with parameter $\rho_{CA}^{branded}$ and other prices $\mathbf{p}_{-j,CA}$.

7.5 Additional Tables of counterfactuals

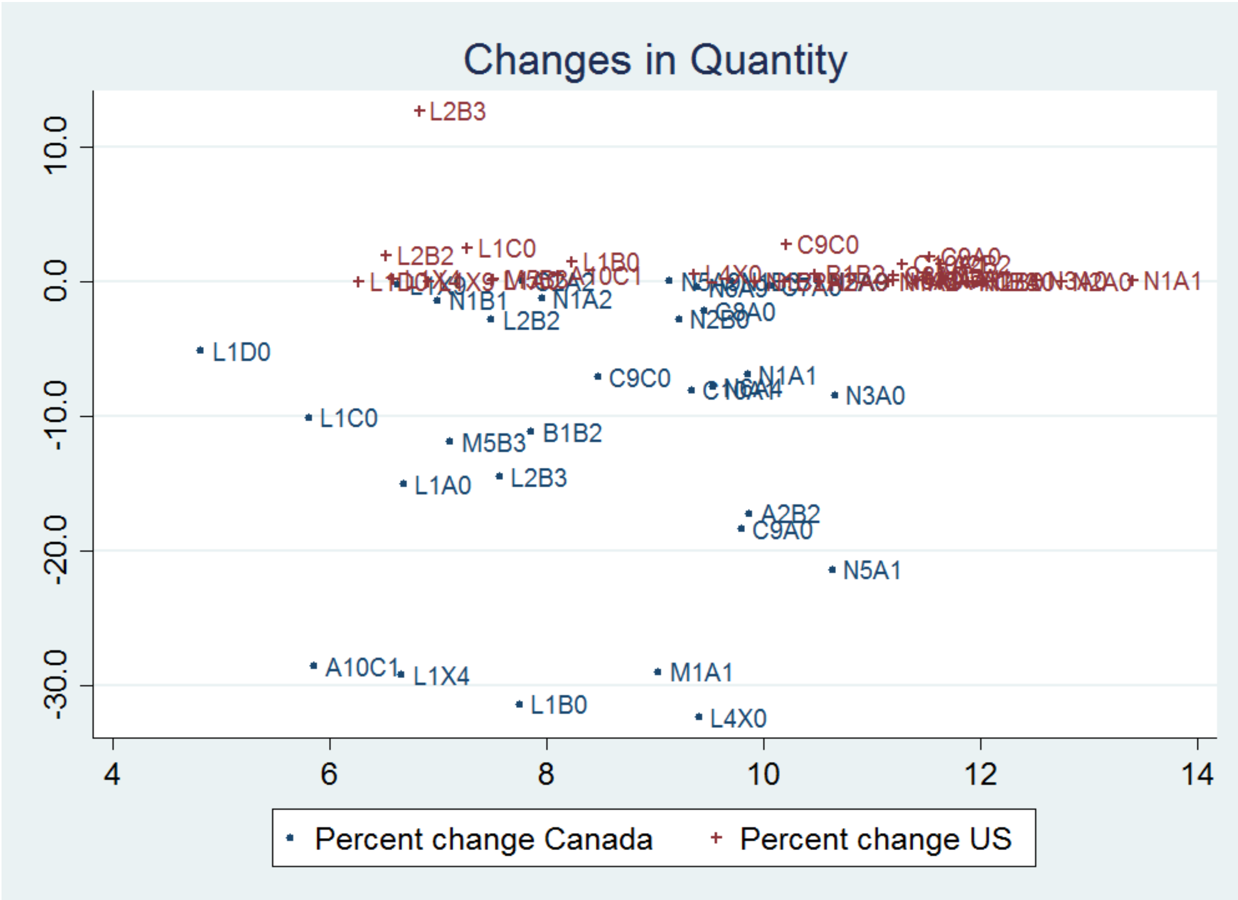
7.5.1 Counterfactuals with Canada as Price Ceiling for the US

Table 7.5: *Counterfactual Quantity Changes on All Drugs when Canada as Price Ceiling for the US*

ATC4	ρ_{jm} On Patent	Branded Off	Generic	Canada Before	After	Δ (%)	US Before	After	Δ (%)
A10C1	0.62			349	249	-28.6	3302	3317	0.5
A2B2	0.55	0.90	0.87	19362	16020	-17.3	113244	114653	1.2
B1B2	0.70			2598	2306	-11.2	35354	35556	0.6
C10A1	0.54	1.00	0.77	11349	10431	-8.1	79186	80203	1.3
C2A2	1.00	1.00	0.94	2384	2384	0.0	26882	26882	-0.0
C7A0	0.72	1.00	1.00	23492	23401	-0.4	167276	167278	0.0
C8A0	0.56	0.89	0.86	12760	12477	-2.2	73390	73697	0.4
C9A0	0.47	0.95	1.00	18050	14721	-18.4	101954	103864	1.9
C9C0	0.60	0.94	0.50	4801	4458	-7.1	27227	27982	2.8
L1A0	0.91	0.50	1.00	795	675	-15.1	1793	1795	0.1
L1B0	0.64	0.50	1.00	2320	1591	-31.4	3737	3791	1.4
L1C0	0.50	0.50	0.98	332	299	-10.2	1424	1460	2.5
L1D0	0.99	0.50	0.50	123	116	-5.2	522	522	0.0
L1X4	1.00	0.50	0.50	785	556	-29.3	722	723	0.1
L1X9	0.92	0.50	0.57	755	753	-0.3	994	994	0.0
L2B2	0.83	0.94	0.61	1791	1739	-2.9	677	690	2.0
L2B3	0.70	0.79	0.58	1928	1648	-14.6	917	1033	12.7
L4X0	0.95	0.91	1.00	12181	8232	-32.4	11599	11666	0.6
M1A1	0.44	0.91	1.00	8374	5944	-29.0	99443	99592	0.1
M5B3	0.93	0.95	0.54	1225	1079	-11.9	1823	1826	0.2
N1A1	0.45	0.57	1.00	19107	17776	-7.0	665328	665934	0.1
N1A2	1.00	1.00	0.92	2865	2828	-1.3	69548	69548	0.0
N1B1	0.96	1.00	0.75	1096	1080	-1.4	20315	20315	0.0
N1B3	0.50	0.50	0.58	16254	16254	0.0	145882	145882	-0.0
N2A0	0.51	0.78	0.89	36395	36395	-0.0	343829	343829	0.0
N2B0	0.50	0.96	0.88	10159	9870	-2.8	153266	153266	-0.0
N3A0	0.87	0.93	1.00	42619	39004	-8.5	274813	275012	0.1
N5A1	0.86	0.86	0.94	41625	32705	-21.4	115139	115470	0.3
N5A9	0.64	0.97	0.94	9269	9267	-0.0	36694	36694	0.0
N6A4	0.80	0.99	0.91	13805	12720	-7.9	89527	89578	0.1
N6A9	0.27	0.89	0.99	11944	11890	-0.4	72854	72876	0.0
Total				330892	298869	-9.6	2738661	2745930	.2

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.

Figure 7.1: *Changes in quantity by ATC-4 in counterfactual against log quantity observed*



Note: Each point corresponds to one ATC-4 labeled with its code. Percentage changes on vertical axis (not drawing if change larger than 200%). Log quantity on horizontal axis. Both US and Canada on same graph.

Table 7.6: *Counterfactual Expenses on Patented Drugs when Canada as Price Ceiling for the US*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	0.62			4161	5777	38.8	113984	112471	-1.3
A2B2	0.55	0.90	0.87	9018	17984	99.4	182955	184476	0.8
B1B2	0.70			40084	78711	96.4	1261933	1228934	-2.6
C10A1	0.54	1.00	0.77	11938	19425	62.7	139298	141079	1.3
C2A2	1.00	1.00	0.94	761	761	-0.0	8330	8330	0.0
C7A0	0.72	1.00	1.00	311	319	2.9	27376	27387	0.0
C8A0	0.56	0.89	0.86	7317	8807	20.4	47992	48490	1.0
C9A0	0.47	0.95	1.00	6881	7465	8.5	23967	26246	9.5
C9C0	0.60	0.94	0.50	4056	7452	83.7	61146	61340	0.3
L1A0	0.91	0.50	1.00	10281	18019	75.3	170467	169746	-0.4
L1B0	0.64	0.50	1.00	25159	45386	80.4	392044	364805	-6.9
L1C0	0.50	0.50	0.98	74104	84637	14.2	524380	545884	4.1
L1D0	0.99	0.50	0.50	8457	10106	19.5	65298	65527	0.4
L1X4	1.00	0.50	0.50	49887	63476	27.2	83505	83278	-0.3
L1X9	0.92	0.50	0.57	18322	18545	1.2	129433	129361	-0.1
L2B2	0.83	0.94	0.61	2638	3473	31.7	6229	6442	3.4
L2B3	0.70	0.79	0.58	9158	15905	73.7	10671	10439	-2.2
L4X0	0.95	0.91	1.00	35121	95430	171.7	152335	152260	-0.0
M1A1	0.44	0.91	1.00	438	1476	237.0	2867	3268	14.0
M5B3	0.93	0.95	0.54	1238	1413	14.1	27912	27806	-0.4
N1A1	0.45	0.57	1.00	6900	8619	24.9	350707	350088	-0.2
N1A2	1.00	1.00	0.92	1192	1171	-1.8	70722	70740	0.0
N1B1	0.96	1.00	0.75	1456	1508	3.5	31019	31035	0.0
N1B3	0.50	0.50	0.58	923	923	-0.0	1362	1362	-0.0
N2A0	0.51	0.78	0.89	346	346	-0.0	870	871	0.1
N2B0	0.50	0.96	0.88	180	273	51.3	18975	18976	0.0
N3A0	0.87	0.93	1.00	3541	6502	83.6	195096	195655	0.3
N5A1	0.86	0.86	0.94	32795	67883	107.0	966832	962088	-0.5
N5A9	0.64	0.97	0.94	1716	1716	0.0	1153	1154	0.1
N6A4	0.80	0.99	0.91	2473	2371	-4.1	113105	113115	0.0
N6A9	0.27	0.89	0.99	341	344	0.8	4674	4738	1.4
Total				371191	596221	60.62	5186638	5147393	-.75

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

Table 7.7: *Counterfactual Price Changes by ATC-4 when Canada as Price Ceiling for the US*

	ρ_{jm}			Price Change All drugs		Price Change Patented		Price Change Branded Off		Price Change Generic	
ATC4	On Patent	Branded Off	Generic	CA (%)	US (%)	CA (%)	US (%)	CA (%)	US (%)	CA (%)	US (%)
A10C1	0.62			81.1	-1.7	81.1	-1.7				
A2B2	0.55	0.90	0.87	132.1	-0.7	197.6	-1.3	88.2	-0.1	23.9	-0.1
B1B2	0.70			122.1	-3.1	122.1	-3.2		-2.1		0.0
C10A1	0.54	1.00	0.77	78.5	-0.8	117.8	-2.6	166.8	-1.7	36.0	-0.2
C2A2	1.00	1.00	0.94	-0.0	0.0	-0.0	0.0	0.0	0.0	-0.0	0.0
C7A0	0.72	1.00	1.00	1.5	0.0	3.3	-0.1	0.5	0.0	1.1	0.0
C8A0	0.56	0.89	0.86	25.9	-1.1	43.0	-2.8	16.3	0.4	17.7	-0.2
C9A0	0.47	0.95	1.00	29.1	1.9	66.1	-6.5	1.8	0.0	5.4	-0.1
C9C0	0.60	0.94	0.50	92.6	-2.3	104.9	-2.9	19.5	0.4	1.7	-0.8
L1A0	0.91	0.50	1.00	111.6	-0.6	212.7	-1.3	16.8	-0.6	133.9	0.0
L1B0	0.64	0.50	1.00	156.4	-8.5	199.3	-21.7	-0.5	-3.0	118.4	-0.4
L1C0	0.50	0.50	0.98	26.8	0.6	66.9	-4.6	-1.5	0.2	6.6	-0.1
L1D0	0.99	0.50	0.50	21.0	0.1	173.6	-0.5	-3.0	-0.0	2.3	-0.0
L1X4	1.00	0.50	0.50	81.6	-0.4	85.4	-0.4	3.8		0.0	0.0
L1X9	0.92	0.50	0.57	1.6	-0.1	52.8	-0.5	1.5		2.2	0.0
L2B2	0.83	0.94	0.61	31.3	1.6	245.1	-3.9	15.5	0.3	10.1	0.1
L2B3	0.70	0.79	0.58	101.7	-13.4	104.6	-14.0	19.0	-0.4	11.2	-0.0
L4X0	0.95	0.91	1.00	312.0	-0.9	329.7	-1.2	5.2	-0.1	126.9	0.0
M1A1	0.44	0.91	1.00	358.0	1.1	104.4	-17.1	63.6	-0.1	494.4	-0.0
M5B3	0.93	0.95	0.54	24.8	-0.5	56.6	-0.8	21.1	0.3	2.4	-0.1
N1A1	0.45	0.57	1.00	35.4	-0.4	48.1	-0.7	23.0	-0.1	25.0	0.0
N1A2	1.00	1.00	0.92	2.3	0.0	41.4	-0.1	1.8	-0.0	1.4	0.0
N1B1	0.96	1.00	0.75	6.7	0.0	16.2	-0.0	10.1	-0.0	4.3	0.0
N1B3	0.50	0.50	0.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N2A0	0.51	0.78	0.89	0.0	0.0	0.1	-0.1	-0.0	-0.0	0.0	0.0
N2B0	0.50	0.96	0.88	29.0	0.0	4.5	0.0	22.8	0.0	30.3	0.0
N3A0	0.87	0.93	1.00	116.5	0.0	128.8	-0.5	79.2	-0.0	132.3	0.0
N5A1	0.86	0.86	0.94	136.5	-0.7	374.2	-1.0	52.3	0.2	49.1	0.4
N5A9	0.64	0.97	0.94	0.0	-0.0	0.5	-0.3	-0.0	0.0	0.0	0.0
N6A4	0.80	0.99	0.91	9.5	-0.1	146.8	-0.4	0.4	-0.1	0.4	0.0
N6A9	0.27	0.89	0.99	1.1	0.0	6.4	-3.1	-0.1	-0.0	0.8	0.0

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

Table 7.8: *Counterfactual Prices of Drugs on Patent present in both US and Canada when Canada as Price Ceiling for the US*

	Before		After			
	Canada	US	Canada		US	
ATC4	Price	Price	Price	Δ (%)	Price	Δ (%)
A10C1	12.8661	36.95631	28.68712	122.97	36.33642	-1.68
A2B2	.8079825	2.675094	2.697367	233.84	2.638698	-1.36
B1B2	15.55126	38.01187	37.48726	141.06	36.81441	-3.15
C10A1	1.770697	3.82358	3.857452	117.85	3.676275	-3.85
C2A2	54.75095	13.18811	54.74297	-0.01	13.18826	0.00
C7A0	1.244643	7.688396	2.174808	74.73	7.643762	-0.58
C8A0	1.268361	2.297664	2.244284	76.94	2.229781	-2.95
C9A0	.5956708	1.685162	1.66685	179.83	1.553767	-7.80
C9C0	1.094559	2.528681	2.301818	110.30	2.441019	-3.47
L1A0	24.69844	198.238	77.59502	214.17	195.6298	-1.32
L1B0	17.69059	248.5182	67.17113	279.70	191.2764	-23.03
L1C0	471.2581	1033.659	941.1678	99.71	978.6742	-5.32
L1D0	292.0294	780.7533	1259.364	331.25	778.822	-0.25
L1X4	66.59953	99.22975	125.9008	89.04	98.87067	-0.36
L1X9	647.0916	745.1591	993.0546	53.46	737.4075	-1.04
L2B2	10.43049	32.88236	35.99053	245.05	30.63242	-6.84
L2B3	4.868706	11.67673	10.1707	108.90	9.953807	-14.76
L4X0	3.17295	9.958714	14.10345	344.49	9.872184	-0.87
M1A1	.6490896	2.914528	2.132971	228.61	2.231462	-23.44
M5B3	6.017537	14.48667	17.12974	184.66	14.33339	-1.06
N1A1	.662663	.919805	1.02603	54.83	.9137184	-0.66
N1A2	12.79765	75.2755	31.65229	147.33	75.17899	-0.13
N1B1	13.03696	16.28716	16.25504	24.68	16.27825	-0.05
N1B3						
N2A0	1.003563	3.317234	3.377676	236.57	3.313498	-0.11
N2B0						
N3A0	1.384019	3.735585	3.399423	145.62	3.694843	-1.09
N5A1	1.760912	8.886744	8.998435	411.01	8.755308	-1.48
N5A9	.8207119	1.356838	1.303776	58.86	1.313062	-3.23
N6A4	1.334195	3.653124	3.66085	174.39	3.634008	-0.52
N6A9	.6356424	3.21982	1.843886	190.08	3.059738	-4.97

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 7.9: *Counterfactual Consumer Welfare Changes on All Drugs when Canada as Price Ceiling for the US*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	0.62			885	984	11.3	11159	11317	1.4
A2B2	0.55	0.90	0.87	56646	42825	-24.4	337119	339633	0.7
B1B2	0.70			8804	6711	-23.8	120918	123494	2.1
C10A1	0.54	1.00	0.77	37661	30663	-18.6	242072	245518	1.4
C2A2	1.00	1.00	0.94	7111	7111	0.0	88937	88936	-0.0
C7A0	0.72	1.00	1.00	62951	62610	-0.5	675640	675647	0.0
C8A0	0.56	0.89	0.86	44044	40952	-7.0	230677	232046	0.6
C9A0	0.47	0.95	1.00	51194	46325	-9.5	335249	337842	0.8
C9C0	0.60	0.94	0.50	16875	14186	-15.9	72193	73773	2.2
L1A0	0.91	0.50	1.00	2395	1835	-23.4	6204	6220	0.3
L1B0	0.64	0.50	1.00	6643	4688	-29.4	12862	13171	2.4
L1C0	0.50	0.50	0.98	855	773	-9.6	4061	4119	1.4
L1D0	0.99	0.50	0.50	363	336	-7.5	2161	2162	0.0
L1X4	1.00	0.50	0.50	2126	1725	-18.9	2109	2116	0.3
L1X9	0.92	0.50	0.57	2431	2413	-0.8	3561	3562	0.0
L2B2	0.83	0.94	0.61	6150	5700	-7.3	2158	2181	1.1
L2B3	0.70	0.79	0.58	5894	4575	-22.4	2478	2806	13.3
L4X0	0.95	0.91	1.00	35194	20803	-40.9	29593	29734	0.5
M1A1	0.44	0.91	1.00	27343	16265	-40.5	389901	390104	0.1
M5B3	0.93	0.95	0.54	3244	2908	-10.4	5887	5913	0.4
N1A1	0.45	0.57	1.00	55089	49074	-10.9	2307142	2313437	0.3
N1A2	1.00	1.00	0.92	9216	9144	-0.8	260259	260260	0.0
N1B1	0.96	1.00	0.75	2969	2898	-2.4	76524	76527	0.0
N1B3	0.50	0.50	0.58	48316	48316	0.0	736051	736050	-0.0
N2A0	0.51	0.78	0.89	108236	108233	-0.0	1145022	1145022	0.0
N2B0	0.50	0.96	0.88	34712	31972	-7.9	618698	618692	-0.0
N3A0	0.87	0.93	1.00	138685	109393	-21.1	830380	830730	0.0
N5A1	0.86	0.86	0.94	128719	97672	-24.1	335035	337240	0.7
N5A9	0.64	0.97	0.94	31051	31047	-0.0	128193	128195	0.0
N6A4	0.80	0.99	0.91	124721	123535	-1.0	327380	327671	0.1
N6A9	0.27	0.89	0.99	31311	31172	-0.4	240522	240599	0.0
Total				1091834	956844	-12.3	9580145	9604719	.2

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 7.10: *Counterfactual Expenses, profits and Consumer Welfare Global Changes on All Drugs when Canada as Price Ceiling for the US*

	Expenses			Profits			Welfare		
ATC4	Before	After	Δ (%)	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	118145	118248	0.1	100914	101048	0.1	12044	12301	2.1
A2B2	284788	298546	4.8	154494	166240	7.6	393765	382458	-2.9
B1B2	1366755	1371139	0.3	1317110	1319003	0.1	129722	130205	0.4
C10A1	186216	196756	5.7	101991	110023	7.9	279733	276181	-1.3
C2A2	38062	38063	0.0	5699	5699	0.0	96048	96048	-0.0
C7A0	148647	148697	0.0	32590	32639	0.1	738591	738257	-0.0
C8A0	259058	259921	0.3	107268	109296	1.9	274721	272998	-0.6
C9A0	66957	69790	4.2	20155	21663	7.5	386443	384167	-0.6
C9C0	68047	71655	5.3	35648	38387	7.7	89068	87959	-1.2
L1A0	244904	253235	3.4	103496	112307	8.5	8599	8055	-6.3
L1B0	482675	479282	-0.7	214305	221685	3.4	19504	17859	-8.4
L1C0	720750	753126	4.5	320143	338649	5.8	4917	4893	-0.5
L1D0	192101	195651	1.8	75846	78384	3.3	2525	2498	-1.1
L1X4	135841	149569	10.1	94154	107787	14.5	4236	3841	-9.3
L1X9	160825	160989	0.1	77580	77794	0.3	5993	5975	-0.3
L2B2	10886	12162	11.7	6970	8056	15.6	8307	7881	-5.1
L2B3	20259	26822	32.4	15144	21106	39.4	8372	7381	-11.8
L4X0	313040	378839	21.0	114726	180293	57.2	64787	50538	-22.0
M1A1	28109	32044	14.0	3911	7189	83.8	417244	406369	-2.6
M5B3	33507	33770	0.8	21752	22009	1.2	9131	8820	-3.4
N1A1	558890	561233	0.4	362079	364754	0.7	2362231	2362511	0.0
N1A2	642266	642396	0.0	170936	171068	0.1	269475	269404	-0.0
N1B1	93051	93285	0.3	25374	25599	0.9	79494	79424	-0.1
N1B3	167484	167484	-0.0	29296	29296	0.0	784366	784366	-0.0
N2A0	486180	486182	0.0	65131	65133	0.0	1253258	1253255	-0.0
N2B0	84433	85358	1.1	13931	14791	6.2	653410	650664	-0.4
N3A0	450060	460845	2.4	127309	137569	8.1	969065	940123	-3.0
N5A1	1113479	1172218	5.3	596356	653992	9.7	463754	434912	-6.2
N5A9	51146	51144	-0.0	6999	6999	0.0	159244	159242	-0.0
N6A4	155712	155563	-0.1	75488	75542	0.1	452101	451206	-0.2
N6A9	48988	49026	0.1	15027	15036	0.1	271833	271771	-0.0
Total	8731260	8973041	2.7	4411821	4639034	5.1	10671980	10561564	-1

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 7.11: *Counterfactual Prices when US is using Canada as Maximum Reference Price*

	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
A10C1	12.05	37.13	21.83	36.51	12.05	37.13	21.83	36.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2B2	0.76	2.44	1.76	2.42	0.83	2.75	2.46	2.71	0.67	3.43	1.27	3.43	0.59	0.63	0.73	0.63
B1B2	15.65	37.61	34.77	36.45	15.65	38.01	34.77	36.81	0.00	30.42	0.00	29.78	0.00	28.47	0.00	28.47
C10A1	1.32	2.23	2.36	2.21	1.77	3.43	3.86	3.34	1.99	2.32	5.32	2.28	0.49	0.50	0.66	0.50
C2A2	0.60	1.35	0.60	1.35	46.08	13.16	46.07	13.16	2.79	2.09	2.79	2.09	0.16	1.06	0.16	1.06
C7A0	0.22	0.87	0.22	0.87	0.30	3.37	0.31	3.37	1.11	2.14	1.12	2.14	0.18	0.60	0.18	0.60
C8A0	0.93	3.40	1.17	3.36	1.30	2.32	1.86	2.25	0.83	25.38	0.97	25.50	0.49	1.17	0.58	1.16
C9A0	0.52	0.51	0.67	0.52	0.68	1.68	1.13	1.57	0.51	1.70	0.52	1.70	0.26	0.30	0.28	0.30
C9C0	0.97	2.31	1.87	2.26	1.10	2.72	2.26	2.64	1.19	2.64	1.42	2.65	0.25	0.47	0.26	0.46
L1A0	17.69	135.17	37.44	134.39	24.69	229.55	77.20	226.60	1.53	109.79	1.79	109.11	14.51	48.55	33.95	48.56
L1B0	16.27	124.41	41.71	113.83	18.00	382.37	53.88	299.26	17.90	209.39	17.81	203.15	11.15	17.12	24.34	17.04
L1C0	270.87	443.02	343.38	445.82	468.30	999.85	781.79	953.96	110.03	350.44	108.43	350.99	86.50	73.89	92.17	73.82
L1D0	164.08	322.95	198.49	323.12	250.68	1350.26	685.96	1342.95	360.70	998.83	350.01	998.49	77.61	108.92	79.41	108.91
L1X4	66.23	112.85	120.27	112.42	66.35	112.77	123.04	112.33	65.16	0.00	67.65	0.00	25.55	146.05	25.56	146.05
L1X9	20.64	138.60	20.98	138.49	642.79	741.55	982.29	738.00	0.94	0.00	0.95	0.00	1.64	15.12	1.67	15.12
L2B2	2.19	10.08	2.87	10.24	10.43	30.28	35.99	29.09	1.45	9.63	1.67	9.66	0.69	1.31	0.75	1.31
L2B3	4.81	11.29	9.70	9.78	4.88	11.75	9.99	10.11	3.80	17.52	4.52	17.45	2.23	0.52	2.49	0.52
L4X0	3.07	23.46	12.67	23.25	3.01	18.79	12.93	18.57	0.75	5.92	0.79	5.91	5.29	59.29	12.01	59.32
M1A1	0.19	0.27	0.88	0.28	0.67	3.68	1.38	3.05	0.50	0.95	0.82	0.95	0.13	0.23	0.75	0.23
M5B3	2.11	18.17	2.64	18.08	2.43	27.81	3.81	27.59	3.21	19.98	3.89	20.04	1.40	2.49	1.43	2.49
N1A1	0.81	0.82	1.09	0.82	0.79	0.92	1.18	0.91	0.92	0.76	1.13	0.76	0.26	0.54	0.33	0.54
N1A2	5.00	9.03	5.11	9.03	11.73	76.79	16.59	76.72	5.43	18.96	5.53	18.96	4.53	5.96	4.59	5.96
N1B1	4.48	4.35	4.78	4.35	10.97	15.64	12.75	15.63	4.63	6.76	5.10	6.76	3.19	2.84	3.32	2.84
N1B3	0.92	1.11	0.92	1.11	6.68	23.42	6.68	23.42	1.04	3.90	1.04	3.90	0.39	0.85	0.39	0.85
N2A0	0.59	1.36	0.59	1.36	0.77	3.20	0.77	3.20	1.18	3.86	1.18	3.86	0.48	1.14	0.48	1.14
N2B0	0.31	0.53	0.40	0.53	0.56	14.59	0.58	14.59	0.34	1.34	0.42	1.34	0.30	0.39	0.39	0.39
N3A0	0.26	1.49	0.57	1.50	1.36	4.30	3.12	4.28	0.20	5.65	0.35	5.65	0.20	0.79	0.45	0.79
N5A1	1.77	9.09	4.20	9.03	1.82	10.36	8.63	10.25	3.09	4.92	4.71	4.93	0.43	3.43	0.65	3.44
N5A9	0.46	1.27	0.46	1.27	2.90	2.76	2.91	2.75	1.17	16.30	1.17	16.30	0.25	1.11	0.25	1.11
N6A4	0.48	1.61	0.53	1.61	1.35	3.61	3.32	3.60	1.44	4.22	1.45	4.22	0.28	0.48	0.29	0.48
N6A9	0.19	0.63	0.19	0.63	0.40	2.95	0.43	2.86	0.58	3.47	0.58	3.47	0.13	0.32	0.13	0.32

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

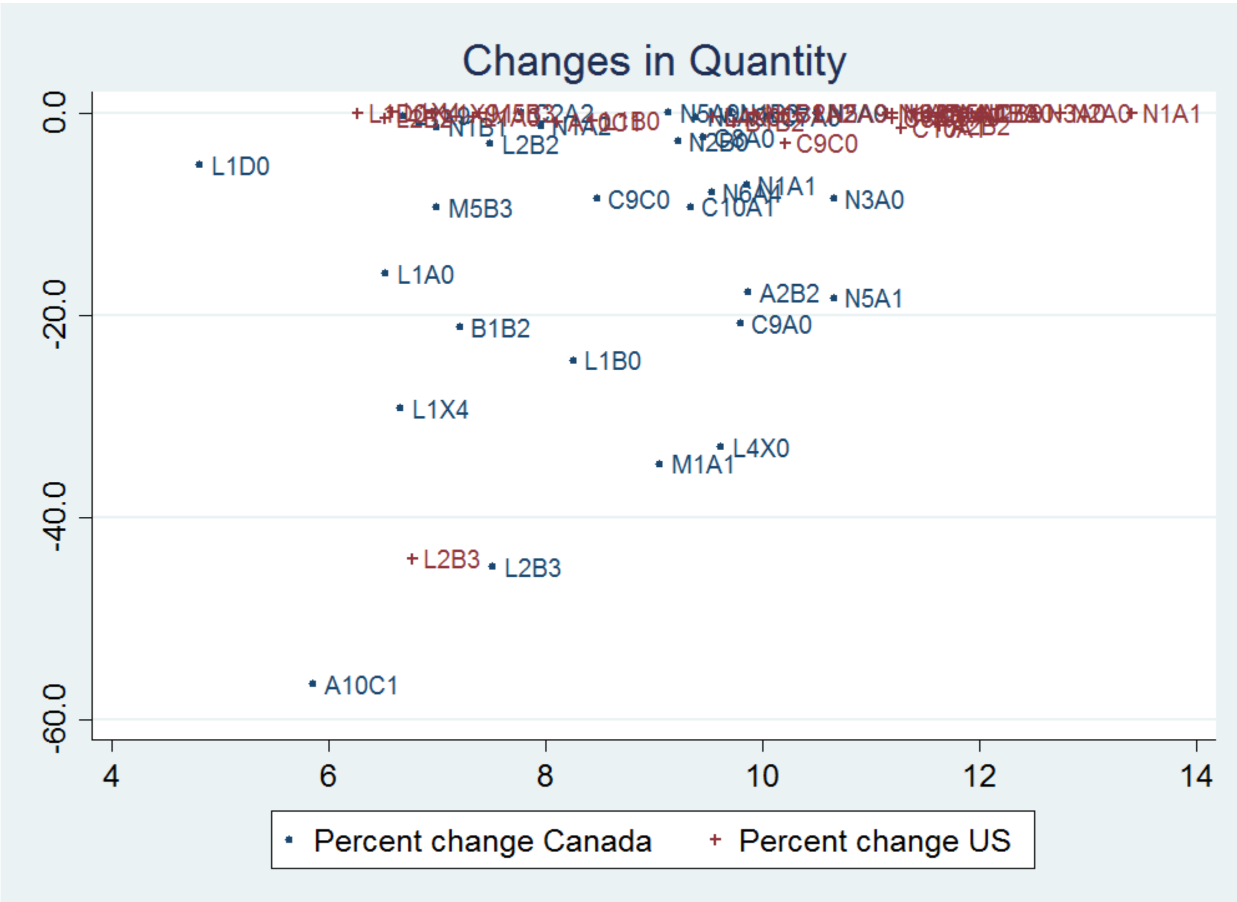
7.5.2 Counterfactuals with US as Price Floor for the Canada

Table 7.12: *Counterfactual Quantity on All Drugs when US as Price Floor for Canada*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	0.62			349	152	-56.5	3304	3275	-0.9
A2B2	0.55	0.90	0.87	19362	15912	-17.8	113244	111835	-1.2
B1B2	0.70			1356	1068	-21.3	16922	16763	-0.9
C10A1	0.54	1.00	0.77	11349	10290	-9.3	79186	78021	-1.5
C2A2	1.00	1.00	0.94	2384	2384	0.0	26882	26882	-0.0
C7A0	0.72	1.00	1.00	23492	23400	-0.4	167276	167274	-0.0
C8A0	0.56	0.89	0.86	12760	12441	-2.5	73390	73001	-0.5
C9A0	0.47	0.95	1.00	18050	14289	-20.8	101961	101544	-0.4
C9C0	0.60	0.94	0.50	4801	4391	-8.5	27227	26413	-3.0
L1A0	0.91	0.50	1.00	680	572	-15.9	1521	1515	-0.4
L1B0	0.64	0.50	1.00	3855	2910	-24.5	4578	4543	-0.8
L1D0	0.99	0.50	0.50	123	116	-5.2	522	522	0.0
L1X4	1.00	0.50	0.50	785	556	-29.3	722	723	0.1
L1X9	0.92	0.50	0.57	799	796	-0.3	1039	1039	-0.0
L2B2	0.83	0.94	0.61	1791	1735	-3.1	677	673	-0.6
L2B3	0.70	0.79	0.58	1838	1012	-44.9	866	484	-44.1
L4X0	0.95	0.91	1.00	15038	10061	-33.1	13925	13868	-0.4
M1A1	0.44	0.91	1.00	8560	5585	-34.8	101620	101592	-0.0
M5B3	0.93	0.95	0.54	1096	993	-9.4	1614	1614	0.0
N1A1	0.45	0.57	1.00	19107	17729	-7.2	665328	664659	-0.1
N1A2	1.00	1.00	0.92	2865	2828	-1.3	69548	69548	0.0
N1B1	0.96	1.00	0.75	1096	1080	-1.5	20315	20314	-0.0
N1B3	0.50	0.50	0.58	16254	16254	0.0	145882	145882	-0.0
N2A0	0.51	0.78	0.89	36395	36395	-0.0	343829	343829	-0.0
N2B0	0.50	0.96	0.88	10159	9870	-2.8	153266	153266	-0.0
N3A0	0.87	0.93	1.00	42619	38975	-8.5	274813	274734	-0.0
N5A1	0.86	0.86	0.94	42666	34843	-18.3	112308	112259	-0.0
N5A9	0.64	0.97	0.94	9269	9267	-0.0	36694	36693	-0.0
N6A4	0.80	0.99	0.91	13805	12712	-7.9	89527	89520	-0.0
N6A9	0.27	0.89	0.99	11944	11888	-0.5	72854	72851	-0.0
Total				334645	300503	-10.2	2720842	2715136	-.2

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.

Figure 7.2: *Changes in quantity by ATC-4 in counterfactual against log quantity observed*



Note: Each point corresponds to one ATC-4 labeled with its code. Percentage changes on vertical axis (not drawing if change larger than 200%). Log quantity on horizontal axis. Both US and Canada on same graph.

Table 7.13: *Counterfactual Expenses on Patented Drugs when US as Price Floor for Canada*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	0.62			4161	7698	85.0	114540	118714	3.6
A2B2	0.55	0.90	0.87	9018	18401	104.0	182955	181462	-0.8
B1B2	0.70			20119	39542	96.5	478597	495483	3.5
C10A1	0.54	1.00	0.77	11938	20641	72.9	139298	136735	-1.8
C2A2	1.00	1.00	0.94	761	761	-0.0	8330	8330	0.0
C7A0	0.72	1.00	1.00	311	320	2.9	27376	27375	-0.0
C8A0	0.56	0.89	0.86	7317	9002	23.0	47992	47297	-1.4
C9A0	0.47	0.95	1.00	6881	7511	9.1	23987	23454	-2.2
C9C0	0.60	0.94	0.50	4056	8191	102.0	61146	60823	-0.5
L1A0	0.91	0.50	1.00	9394	18724	99.3	152325	155363	2.0
L1B0	0.64	0.50	1.00	31685	70195	121.5	496763	508524	2.4
L1D0	0.99	0.50	0.50	8457	10107	19.5	65298	65493	0.3
L1X4	1.00	0.50	0.50	49887	63475	27.2	83505	83278	-0.3
L1X9	0.92	0.50	0.57	23506	23767	1.1	156957	155799	-0.7
L2B2	0.83	0.94	0.61	2638	3668	39.1	6229	6064	-2.6
L2B3	0.70	0.79	0.58	8706	35275	305.2	10127	7450	-26.4
L4X0	0.95	0.91	1.00	45041	143863	219.4	182953	183078	0.1
M1A1	0.44	0.91	1.00	450	2518	459.9	3195	2979	-6.8
M5B3	0.93	0.95	0.54	1077	1212	12.6	25993	25994	0.0
N1A1	0.45	0.57	1.00	6900	8686	25.9	350707	351757	0.3
N1A2	1.00	1.00	0.92	1192	1171	-1.8	70722	70740	0.0
N1B1	0.96	1.00	0.75	1456	1508	3.6	31019	30997	-0.1
N1B3	0.50	0.50	0.58	923	923	-0.0	1362	1362	-0.0
N2A0	0.51	0.78	0.89	346	346	-0.0	870	870	-0.0
N2B0	0.50	0.96	0.88	180	273	51.3	18975	18976	0.0
N3A0	0.87	0.93	1.00	3541	6527	84.3	195096	194883	-0.1
N5A1	0.86	0.86	0.94	29323	59479	102.8	865930	866139	0.0
N5A9	0.64	0.97	0.94	1716	1716	0.0	1153	1152	-0.1
N6A4	0.80	0.99	0.91	2473	2370	-4.2	113105	113095	-0.0
N6A9	0.27	0.89	0.99	341	344	0.8	4674	4668	-0.1
Total				293793	568212	93.40	3921179	3948336	.69

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

Table 7.14: *Counterfactual Prices by ATC-4 when US as Price Floor for Canada*

	ρ_{jm}			Price Change All drugs		Price Change Patented		Price Change Branded Off		Price Change Generic	
ATC4	*On Patent*	*Branded Off*	*Generic*	CA (%)	US (%)	CA (%)	US (%)	CA (%)	US (%)	CA (%)	US (%)
A10C1	0.62			328.3	5.2	328.3	5.2				
A2B2	0.55	0.90	0.87	138.8	0.6	209.4	1.2	92.1	0.0	24.2	0.1
B1B2	0.70			149.5	4.2	149.5	4.7		2.7		-0.0
C10A1	0.54	1.00	0.77	91.0	0.7	141.9	2.6	184.1	1.7	40.0	0.4
C2A2	1.00	1.00	0.94	-0.0	0.0	-0.0	0.0	0.0	0.0	-0.0	0.0
C7A0	0.72	1.00	1.00	1.5	0.0	3.3	0.1	0.5	-0.0	1.1	0.0
C8A0	0.56	0.89	0.86	29.3	1.5	49.3	3.6	18.4	-0.2	19.9	0.2
C9A0	0.47	0.95	1.00	34.3	-0.5	80.1	1.5	2.1	-0.0	8.3	0.0
C9C0	0.60	0.94	0.50	112.7	2.3	128.2	3.0	23.0	-0.2	1.8	0.5
L1A0	0.91	0.50	1.00	147.1	2.5	262.0	5.7	15.5	0.1	160.3	-0.0
L1B0	0.64	0.50	1.00	214.8	3.2	289.8	12.4	-1.4	0.0	164.9	-0.1
L1D0	0.99	0.50	0.50	21.0	0.0	174.1	-0.5	-3.0	-0.0	2.3	-0.0
L1X4	1.00	0.50	0.50	81.6	-0.4	85.4	-0.4	3.8		0.0	0.0
L1X9	0.92	0.50	0.57	1.5	-0.6	48.9	0.1	1.4		2.1	-0.0
L2B2	0.83	0.94	0.61	37.9	-2.7	320.5	0.5	16.9	0.2	11.1	-0.2
L2B3	0.70	0.79	0.58	612.1	29.2	648.0	33.1	24.4	0.1	15.5	0.0
L4X0	0.95	0.91	1.00	392.3	0.6	414.7	0.8	5.6	0.0	158.4	-0.0
M1A1	0.44	0.91	1.00	769.3	-0.7	607.0	6.0	186.8	0.0	936.3	-0.0
M5B3	0.93	0.95	0.54	22.4	-0.0	53.8	-0.0	21.3	0.0	2.4	0.0
N1A1	0.45	0.57	1.00	36.7	0.4	50.1	0.8	23.5	-0.0	26.2	-0.1
N1A2	1.00	1.00	0.92	2.3	0.0	41.4	-0.1	1.8	-0.0	1.4	0.0
N1B1	0.96	1.00	0.75	6.7	-0.0	16.4	0.1	10.1	-0.0	4.3	-0.0
N1B3	0.50	0.50	0.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N2A0	0.51	0.78	0.89	0.0	0.0	0.1	0.0	-0.0	0.0	0.0	0.0
N2B0	0.50	0.96	0.88	29.0	0.0	4.5	0.0	22.8	0.0	30.3	0.0
N3A0	0.87	0.93	1.00	117.4	-0.0	132.8	0.2	79.6	0.0	133.3	-0.0
N5A1	0.86	0.86	0.94	121.3	0.1	372.1	0.1	47.8	-0.1	51.4	-0.0
N5A9	0.64	0.97	0.94	0.0	0.0	0.5	0.3	-0.0	-0.0	0.0	0.0
N6A4	0.80	0.99	0.91	9.5	0.0	149.6	0.1	0.5	0.0	0.4	-0.0
N6A9	0.27	0.89	0.99	1.2	0.0	6.7	0.5	-0.1	0.0	0.8	0.0

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

Table 7.15: *Counterfactual Prices of Drugs on Patent present in both US and Canada when US as Price Floor for Canada*

	Before		After			
	Canada	US	Canada		US	
ATC4	Price	Price	Price	Δ (%)	Price	Δ (%)
A10C1	12.14421	37.09733	61.24129	404.28	39.06341	5.30
A2B2	.8079825	2.675094	2.821949	249.26	2.70827	1.24
B1B2	15.36494	37.85803	41.56478	170.52	39.64621	4.72
C10A1	1.770697	3.82358	4.284205	141.95	3.982836	4.17
C2A2	54.75095	13.18811	54.72902	-0.04	13.18826	0.00
C7A0	1.244643	7.688396	2.185894	75.62	7.714972	0.35
C8A0	1.268361	2.297664	2.40667	89.75	2.385341	3.82
C9A0	.5887031	1.685948	2.012465	241.85	1.717792	1.89
C9C0	1.094559	2.528681	2.574439	135.20	2.621561	3.67
L1A0	25.97724	205.1478	95.36224	267.10	216.579	5.57
L1B0	17.3866	268.2582	97.04	458.13	306.8802	14.40
L1D0	292.0294	780.7533	1263.382	332.62	779.0521	-0.22
L1X4	66.59953	99.22975	125.893	89.03	98.87096	-0.36
L1X9	753.4308	886.57	1125.542	49.39	887.5515	0.11
L2B2	10.43049	32.88236	43.86275	320.52	33.14288	0.79
L2B3	4.865076	11.75005	39.00875	701.81	16.18691	37.76
L4X0	3.320533	10.59573	17.55219	428.60	10.66112	0.62
M1A1	.6708143	2.973108	6.520396	872.01	3.234343	8.79
M5B3	6.807281	16.13616	18.41846	170.57	16.13214	-0.02
N1A1	.662663	.919805	1.044167	57.57	.9271347	0.80
N1A2	12.79765	75.2755	31.65223	147.33	75.17893	-0.13
N1B1	13.03696	16.28716	16.27862	24.87	16.30099	0.08
N1B3						
N2A0	1.003563	3.317234	3.382701	237.07	3.317749	0.02
N2B0						
N3A0	1.384019	3.735585	3.464821	150.34	3.752379	0.45
N5A1	1.869504	9.782676	9.571216	411.97	9.7985	0.16
N5A9	.8207119	1.356838	1.388645	69.20	1.396926	2.95
N6A4	1.334195	3.653124	3.710609	178.12	3.656124	0.08
N6A9	.6356424	3.21982	2.009834	216.19	3.244288	0.76

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 7.16: *Counterfactual Consumer Welfare Changes on All Drugs when US as Price Floor for Canada*

	ρ_{jm}			Canada			US		
ATC4	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	0.62			885	820	-7.3	11159	10912	-2.2
A2B2	0.55	0.90	0.87	56646	42488	-25.0	337119	335034	-0.6
B1B2	0.70			3914	2712	-30.7	55450	53879	-2.8
C10A1	0.54	1.00	0.77	37661	29862	-20.7	242072	238483	-1.5
C2A2	1.00	1.00	0.94	7111	7112	0.0	88937	88936	-0.0
C7A0	0.72	1.00	1.00	62951	62608	-0.5	675640	675626	-0.0
C8A0	0.56	0.89	0.86	44044	40615	-7.8	230677	229045	-0.7
C9A0	0.47	0.95	1.00	51194	45660	-10.8	335249	334683	-0.2
C9C0	0.60	0.94	0.50	16875	13793	-18.3	72193	70600	-2.2
L1A0	0.91	0.50	1.00	2092	1570	-24.9	5245	5204	-0.8
L1B0	0.64	0.50	1.00	10952	8058	-26.4	15958	15786	-1.1
L1D0	0.99	0.50	0.50	363	336	-7.5	2161	2162	0.0
L1X4	1.00	0.50	0.50	2126	1725	-18.9	2109	2116	0.3
L1X9	0.92	0.50	0.57	2486	2467	-0.8	3771	3769	-0.1
L2B2	0.83	0.94	0.61	6150	5665	-7.9	2158	2149	-0.4
L2B3	0.70	0.79	0.58	5427	2814	-48.1	2336	1665	-28.7
L4X0	0.95	0.91	1.00	45075	25378	-43.7	35499	35382	-0.3
M1A1	0.44	0.91	1.00	27881	14616	-47.6	397633	397520	-0.0
M5B3	0.93	0.95	0.54	2917	2656	-9.0	5131	5131	0.0
N1A1	0.45	0.57	1.00	55089	48904	-11.2	2307142	2299762	-0.3
N1A2	1.00	1.00	0.92	9216	9144	-0.8	260259	260260	0.0
N1B1	0.96	1.00	0.75	2969	2897	-2.4	76524	76521	-0.0
N1B3	0.50	0.50	0.58	48316	48316	0.0	736051	736050	-0.0
N2A0	0.51	0.78	0.89	108236	108233	-0.0	1145022	1145022	-0.0
N2B0	0.50	0.96	0.88	34712	31972	-7.9	618698	618692	-0.0
N3A0	0.87	0.93	1.00	138685	109231	-21.2	830380	830237	-0.0
N5A1	0.86	0.86	0.94	133543	104407	-21.8	333726	333418	-0.1
N5A9	0.64	0.97	0.94	31051	31046	-0.0	128193	128192	-0.0
N6A4	0.80	0.99	0.91	124721	123527	-1.0	327380	327334	-0.0
N6A9	0.27	0.89	0.99	31311	31166	-0.5	240522	240506	-0.0
Total				1104596	959797	-13.1	9524394	9504077	-.2

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 7.17: *Counterfactual Expenses, profits and Consumer Welfare Global Changes on All Drugs when US as Price Floor for Canada*

	Expenses			Profits			Welfare		
ATC4	Before	After	Δ (%)	Before	After	Δ (%)	Before	After	Δ (%)
A10C1	118701	126412	6.5	101159	108738	7.5	12044	11732	-2.6
A2B2	284788	296368	4.1	154494	168190	8.9	393765	377522	-4.1
B1B2	628192	667698	6.3	589713	630485	6.9	59364	56592	-4.7
C10A1	186216	195399	4.9	101991	114855	12.6	279733	268345	-4.1
C2A2	38062	38063	0.0	5699	5699	0.0	96048	96048	-0.0
C7A0	148647	148695	0.0	32590	32648	0.2	738591	738234	-0.0
C8A0	259058	264450	2.1	107268	111676	4.1	274721	269660	-1.8
C9A0	66978	67364	0.6	20164	22164	9.9	386443	380343	-1.6
C9C0	68047	71946	5.7	35648	40708	14.2	89068	84393	-5.2
L1A0	219964	235239	6.9	91762	105201	14.6	7336	6774	-7.7
L1B0	610474	679005	11.2	272135	333723	22.6	26910	23844	-11.4
L1D0	192101	195639	1.8	75846	78404	3.4	2525	2498	-1.1
L1X4	135841	149569	10.1	94154	107787	14.5	4236	3841	-9.3
L1X9	194257	193392	-0.4	95351	95906	0.6	6257	6236	-0.3
L2B2	10886	12016	10.4	6970	8310	19.2	8307	7814	-5.9
L2B3	19263	43231	124.4	14346	40579	182.9	7763	4479	-42.3
L4X0	384207	494727	28.8	140623	249700	77.6	80573	60760	-24.6
M1A1	28816	36290	25.9	4139	11752	183.9	425514	412136	-3.1
M5B3	31274	31617	1.1	19780	20121	1.7	8048	7787	-3.2
N1A1	558890	564717	1.0	362079	368412	1.7	2362231	2348666	-0.6
N1A2	642266	642396	0.0	170936	171068	0.1	269475	269404	-0.0
N1B1	93051	93261	0.2	25374	25602	0.9	79494	79418	-0.1
N1B3	167484	167484	-0.0	29296	29296	0.0	784366	784366	-0.0
N2A0	486180	486182	0.0	65131	65133	0.0	1253258	1253254	-0.0
N2B0	84433	85358	1.1	13931	14791	6.2	653410	650664	-0.4
N3A0	450060	460358	2.3	127309	137743	8.2	969065	939468	-3.1
N5A1	1055035	1112993	5.5	546149	604642	10.7	467269	437825	-6.3
N5A9	51146	51148	0.0	6999	7001	0.0	159244	159238	-0.0
N6A4	155712	155639	-0.0	75488	75805	0.4	452101	450861	-0.3
N6A9	48988	49002	0.0	15027	15067	0.3	271833	271672	-0.1
Total	7419016	7815658	5.3	3401549	3801205	11.7	10628991	10463874	-1.5

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 7.18: *Counterfactual Prices when US is using Canada as Maximum Reference Price and ex ante commitment*

	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
A10C1	12.05	37.27	51.61	39.22	12.05	37.27	51.61	39.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2B2	0.76	2.44	1.81	2.45	0.83	2.75	2.56	2.78	0.67	3.43	1.30	3.43	0.59	0.63	0.74	0.64
B1B2	15.14	36.08	37.79	37.60	15.14	37.86	37.79	39.65	0.00	30.42	0.00	31.25	0.00	28.47	0.00	28.47
C10A1	1.32	2.23	2.53	2.24	1.77	3.43	4.28	3.52	1.99	2.32	5.67	2.36	0.49	0.50	0.68	0.50
C2A2	0.60	1.35	0.60	1.35	46.08	13.16	46.06	13.16	2.79	2.09	2.79	2.09	0.16	1.06	0.16	1.06
C7A0	0.22	0.87	0.22	0.87	0.30	3.37	0.31	3.37	1.11	2.14	1.12	2.14	0.18	0.60	0.18	0.60
C8A0	0.93	3.40	1.20	3.45	1.30	2.32	1.94	2.40	0.83	25.38	0.98	25.33	0.49	1.17	0.59	1.17
C9A0	0.52	0.51	0.70	0.51	0.68	1.68	1.22	1.71	0.51	1.70	0.52	1.70	0.26	0.30	0.29	0.30
C9C0	0.97	2.31	2.06	2.36	1.10	2.72	2.52	2.80	1.19	2.64	1.47	2.63	0.25	0.47	0.26	0.47
L1A0	18.64	145.03	46.07	148.60	25.26	248.29	91.44	262.43	1.52	105.28	1.76	105.42	15.51	57.18	40.36	57.18
L1B0	16.21	127.49	51.05	131.58	17.50	401.51	68.22	451.30	28.88	223.27	28.49	223.35	11.06	16.72	29.30	16.70
L1D0	164.08	322.95	198.53	323.10	250.68	1350.26	687.10	1344.01	360.70	998.83	350.01	998.54	77.61	108.92	79.41	108.91
L1X4	66.23	112.85	120.26	112.42	66.35	112.77	123.04	112.33	65.16	0.00	67.65	0.00	25.55	146.05	25.56	146.05
L1X9	25.11	159.47	25.49	158.48	749.23	866.80	1115.65	867.61	0.95	0.00	0.96	0.00	1.56	15.22	1.59	15.22
L2B2	2.19	10.08	3.01	9.81	10.43	30.28	43.86	30.42	1.45	9.63	1.69	9.65	0.69	1.31	0.76	1.31
L2B3	4.80	11.34	34.18	14.66	4.88	11.83	36.49	15.75	3.80	17.52	4.72	17.54	2.23	0.52	2.58	0.52
L4X0	3.22	23.88	15.87	24.03	3.13	18.62	16.10	18.78	0.76	5.84	0.80	5.85	6.01	61.97	15.53	61.95
M1A1	0.19	0.28	1.67	0.27	0.68	3.61	4.77	3.83	0.50	0.94	1.45	0.94	0.13	0.22	1.31	0.22
M5B3	2.17	18.79	2.65	18.79	2.63	30.08	4.05	30.08	3.21	21.10	3.89	21.10	1.40	2.46	1.43	2.46
N1A1	0.81	0.82	1.10	0.82	0.79	0.92	1.19	0.93	0.92	0.76	1.14	0.76	0.26	0.54	0.33	0.54
N1A2	5.00	9.03	5.11	9.03	11.73	76.79	16.59	76.72	5.43	18.96	5.53	18.96	4.53	5.96	4.59	5.96
N1B1	4.48	4.35	4.78	4.34	10.97	15.64	12.76	15.65	4.63	6.76	5.10	6.76	3.19	2.84	3.32	2.84
N1B3	0.92	1.11	0.92	1.11	6.68	23.42	6.68	23.42	1.04	3.90	1.04	3.90	0.39	0.85	0.39	0.85
N2A0	0.59	1.36	0.59	1.36	0.77	3.20	0.77	3.20	1.18	3.86	1.18	3.86	0.48	1.14	0.48	1.14
N2B0	0.31	0.53	0.40	0.53	0.56	14.59	0.58	14.59	0.34	1.34	0.42	1.34	0.30	0.39	0.39	0.39
N3A0	0.26	1.49	0.58	1.49	1.36	4.30	3.17	4.31	0.20	5.65	0.35	5.65	0.20	0.79	0.46	0.79
N5A1	1.68	8.76	3.72	8.76	1.92	10.88	9.06	10.89	3.13	9.60	4.62	9.59	0.40	3.16	0.61	3.16
N5A9	0.46	1.27	0.46	1.27	2.90	2.76	2.91	2.76	1.17	16.30	1.17	16.30	0.25	1.11	0.25	1.11
N6A4	0.48	1.61	0.53	1.61	1.35	3.61	3.36	3.62	1.44	4.22	1.45	4.22	0.28	0.48	0.29	0.48
N6A9	0.19	0.63	0.19	0.63	0.40	2.95	0.43	2.97	0.58	3.47	0.58	3.47	0.13	0.32	0.13	0.32

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

Table 7.19: *Counterfactual Expenses by ATC-4 with varying MFN rule (0, +33%, +50%) and Larger Reference Market (with ex ante commitment)*

			ρ_{jm}			Canada			US		
ATC4	MFN	US Share market	On Patent	Branded Off	Generic	Before	After	Δ (%)	Before	After	Δ (%)
A2B2	0	0	0.55	0.90	0.87	14057	27056	92.5	270730	269312	-0.5
A2B2	0	50	0.55	0.90	0.87	92679	415627	348.5	270730	229192	-15.3
A2B2	0	100	0.55	0.90	0.87	185358	860600	364.3	270730	218992	-19.1
A2B2	33	0	0.55	0.90	0.87	14057	24039	71.0	270730	270848	0.0
A2B2	50	0	0.55	0.90	0.87	14057	22464	59.8	270730	271066	0.1
B1B2	0	0	0.70			20119	39542	96.5	608073	628156	3.3
B1B2	0	50	0.70			135563	279338	106.1	678039	770136	13.6
B1B2	0	100	0.70			238686	620087	159.8	608073	741229	21.9
B1B2	33	0	0.70			20119	29369	46.0	608073	599771	-1.4
B1B2	50	0	0.70			20119	26030	29.4	608073	620713	2.1
L4X0	0	0	0.95	0.91	1.00	48328	158193	227.3	335879	336534	0.2
L4X0	0	50	0.95	0.91	1.00	36593	120167	228.4	346961	347399	0.1
L4X0	0	100	0.95	0.91	1.00	73186	241375	229.8	346961	347999	0.3
L4X0	33	0	0.95	0.91	1.00	53661	128286	139.1	366193	353273	-3.5
L4X0	50	0	0.95	0.91	1.00	53661	98516	83.6	366193	359094	-1.9
N1A1	0	0	0.45	0.57	1.00	15417	19477	26.3	543474	545239	0.3
N1A1	0	50	0.45	0.57	1.00	220806	290984	31.8	543474	569227	4.7
N1A1	0	100	0.45	0.57	1.00	441612	616921	39.7	543474	578469	6.4
N1A1	33	0	0.45	0.57	1.00	15417	16624	7.8	543474	543661	0.0
N1A1	50	0	0.45	0.57	1.00	15417	15631	1.4	543474	543431	-0.0
N1A2	0	0	1.00	1.00	0.92	14275	14395	0.8	627990	628001	0.0
N1A2	0	50	1.00	1.00	0.92	65445	66059	0.9	627990	628042	0.0
N1A2	0	100	1.00	1.00	0.92	130890	132107	0.9	627990	628091	0.0
N1A2	33	0	1.00	1.00	0.92	14275	14345	0.5	627990	628235	0.0
N1A2	50	0	1.00	1.00	0.92	14275	14306	0.2	627990	628182	0.0
N2A0	0	0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N2A0	0	50	0.51	0.78	0.89	108392	108398	0.0	464444	464444	-0.0
N2A0	0	100	0.51	0.78	0.89	216785	216796	0.0	464444	464444	-0.0
N2A0	33	0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N2A0	50	0	0.51	0.78	0.89	21736	21737	0.0	464444	464445	0.0
N3A0	0	0	0.87	0.93	1.00	11366	21817	91.9	438695	438541	-0.0
N3A0	0	50	0.87	0.93	1.00	70808	158094	123.3	438695	437694	-0.2
N3A0	0	100	0.87	0.93	1.00	141617	318854	125.2	438695	436773	-0.4
N3A0	33	0	0.87	0.93	1.00	11366	19574	72.2	438695	440600	0.4
N3A0	50	0	0.87	0.93	1.00	11056	17313	56.6	432920	432944	0.0
N5A1	0	0	0.86	0.86	0.94	72065	129771	80.1	982970	983222	0.0
N5A1	0	50	0.86	0.86	0.94	98298	181237	84.4	982970	983347	0.0
N5A1	0	100	0.86	0.86	0.94	196596	362947	84.6	982970	983687	0.1
N5A1	33	0	0.86	0.86	0.94	72065	116842	62.1	982970	968099	-1.5
N5A1	50	0	0.86	0.86	0.94	72065	106353	47.6	982970	945020	-3.9