Spending and Pricing to Deter Arbitrage

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Abstract

When a firm sells the same good in two markets at different prices but virtually no one in the high-price market purchases in the low-price market, the absence of arbitrage is typically attributed to exogenous "blockades," never to deliberate "arbitrage deterrence." Such deterrence may involve not only limit-pricing but also spending to raise the consumers' cost of arbitrage. I present examples of arbitrage deterrence from three industries: pharmaceuticals, chemicals, and automobiles. Motivated by these three examples, I generalize the standard model of third-degree price discrimination to encompass both blockaded and deterred arbitrage. I also develop a model where the lower of the two prices is negotiated as is done by foreign governments in the case of prescription drugs. In both models, if the government raises the firm's marginal cost of deterring arbitrage, the higher price will fall and the lower one will rise but the firm will continue to deter arbitrage. In the bargaining model, if the absence of arbitrage is mistakenly attributed to exogenous factors when in fact it is the result of deliberate deterrence, econometric estimates of the firm's bargaining power will be biased upwards.

1 Introduction

When a firm sells the same good in two markets at different prices but virtually no one in the high-price market purchases in the low-price market, the absence of arbitrage is typically attributed to exogenous "blockades", never to deliberate "arbitrage deterrence." If arbitrage is blockaded and the firm has a constant marginal cost, then prices in the two markets are independent of each other. The independence assumption is made both in the applied literature on price discrimination (Berndt, 2002; Berndt, 2007; Danzon, 1997; McAfee, 2008) and in the literature where the lower price is set by negotiation rather than only by the firm (Pecorino, 2002; Dubois et al., 2021). While the assumption of market independence unquestionably simplifies analyses, it is sometimes unjustified. When it is, the assumption can lead to misleading policy recommendations, flawed welfare conclusions, and biased econometric estimates.

As a matter of logic, the absence of arbitrage at the *current* price differential hardly means that no arbitrage would occur if the price differential were wider. The observed absence of arbitrage could just as easily occur because the manufacturer is limit pricing or raising consumer costs of arbitrage to deter buyers in the high-price market from shopping in the low-price market. In that case, the two markets are not independent. The *threat* of arbitrage links the two markets even if no arbitrage is occurs.

I distinguish between arbitrage that is exogenously "blockaded" so it would not occur even when a monopoly price is set in each market and arbitrage that is deliberately "deterred." Bain (1956) first made this distinction with regard to entry into an industry and it is widely used in the IO literature. Whenever the manufacturer is observed spending money on deterrence, the absence of arbitrage must be attributed to arbitrage deterrence. For if the manufacturer believed that arbitrage would *never* occur even if it charged the monopoly price in each market, then spending anything on deterrence would be a waste of money. If the expenditures are large, the firm must anticipate that the loss in profits would be even larger if arbitrage occurred.

To see that the two markets are linked if arbitrage is being deterred, suppose the imposition of a regulation results in an inward shift in the demand curve in the low-price market. If arbitrage is exogenously blockaded, then a firm with a constant

marginal cost of production will not change its price in the market where demand has remained stable but may reduce the price in the market with reduced demand. If arbitrage is instead deliberately deterred, such a widening of the price differential would result in a loss of sales in the high-price market as consumers, attracted by the increased savings possible in the other market, switch to that market. To avoid losing the lucrative patronage of these customers, the firm would have to reduce its higher price despite the absence of an exogenous demand shift in the high-price market.

Government policies to curb the firm's arbitrage deterrence may fail to enable cross-market shopping but may benefit consumers in the high-price market in other ways. In both models in this study, for example, a government policy to raise the firm's marginal cost of deterrence induces the firm to reduce the higher of its two prices in order to maintain its arbitrage deterrence. The benefit of this price reduction has been overlooked in recent policy analyses. For example, the Congressional Budget Office in its evaluation of a policy to reduce misleading safety warnings in the international pharmaceutical market, concluded that US consumers would not benefit (CBO 2004). The basis for the CBO's conclusion was its prediction that the policy would have little or no effect on arbitrage; CBO explicitly disregarded the predicted effect of the policy on domestic prices.

When the lower price is set by negotiation, disregarding ongoing arbitrage deterrence can again result in flawed analyses. Thus, the Council of Economic Advisors predicted that if a foreign negotiator had all the bargaining power, it would make a take-it-or-leave-it demand that the pharmaceutical manufacturer set the negotiated price at the marginal cost of production. "The foreign government can insist on a price that covers the marginal production cost—but not the far greater sunk costs from years of research and development,"(CEA 2018, 15).[1] In reality, negotiators in other high-income countries have been unable to bargain the price of hepatitis C cures like Sovaldi below $40,000 per cure despite their marginal cost of production of $100 per cure (Hill et al., 2014). An econometrician viewing this situation and disregarding ongoing arbitrage deterrence would mistakenly conclude that the foreign negotiator had far less bargaining power than the CEA assumed.[2] Of course, if the government

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[1]Grossman and Lai (2008, p. 386) make a similar prediction.

[2]Dubois et al. (2021) estimate bargaining weights in the international pharmaceutical market under

of another high-income country did make a non-negotiable demand that Gilead Sciences sell its Sovaldi at a $100 per cure, that manufacturer would have rejected the proposal out of hand to avoid the massive flight of US customers taking advantage of the bargain price unavailable at home.

To fix ideas, I conclude by considering three real-world examples of arbitrage deterrence. In each case, a firm did not merely narrow the price differential between markets but took additional costly steps to deter arbitrage. In each case, the firm found a way to deter buyers in the high-price market from purchasing in the low-price market without inconveniencing customers for whom the low prices were intended. Two of the examples are historical but the other—the international market in prescription drugs—is of current policy interest. I mention it now but will discuss it in greater detail later in the paper.

On average, the same branded pharmaceuticals are currently more than three times as expensive in the United States as in other high-income countries such as Canada, the UK, France, and Germany (Mulcahy et al., 2021). Random sampling (Bate et al., 2013; Bate, 2019) has shown that online imports of drugs from pharmacies licensed in other high-income countries are as safe as drugs purchased in the United States. Yet less than 1.5 percent of Americans filling their prescriptions (Hong et al., 2020) avail themselves of the huge savings such online imports would allow. This is the result of a multimillion-dollar campaign by pharmaceutical firms, which the Food and Drug Administration (FDA) has not challenged, to convince Americans that online imports from pharmacies licensed in other high-income countries are unsafe; otherwise, these expenditures are a colossal waste of the manufacturers' money.

The deterrence strategy of pharmaceutical manufacturers is reminiscent of a strategy embraced by Röhm and Haas a century ago (Eaton et al., 1999, 466-467). The company was selling a chemical compound used in dentures for more than 25 times the price it was charging industrial buyers. To deter the arbitrage that such a massive price differential would otherwise have stimulated, the company considered adding arsenic to its vastly cheaper industrial product. One of its licensees suggested that "even a millionth of one percent of arsenic or lead might cause [the predecessor of the FDA] to confiscate every bootleg unit in the country." The company initially viewed

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the assumption of market independence.

this suggestion as "a very fine method of controlling the bootleg situation," saying, "We shall take this matter up with our development department and advise you whether any such material could be used" (Stocking and Watkins, 1947, 402-403). Ultimately, wiser heads prevailed. Röhm and Haas decided that it could achieve virtually the same deterrent effect with little or no risk of legal liability by circulating a rumor about arsenic contamination in its industrial product. Ensuring that this false rumor reached potential "bootleggers" must have involved considerable effort and expense in this pre-internet era.

A final example concerns manufacturer warranties on automobiles purchased abroad (Adams, 1989, 175-176). In the early 1980s, FIAT automobiles purchased in the UK were 1.44 times as expensive as those purchased in Belgium (*Economist*, 1983, 62). To deter the British from purchasing their FIATs in Belgium at a huge savings, the manufacturer devised the following restrictions on its warranties (*Common Market Law Reports*, 497-498). Customers could be reimbursed for repairs done at authorized FIAT dealerships other than where the car was purchased but only if the buyer (1) presented the car, once repaired, to the dealership where the purchase originated; (2) also presented the parts replaced and the associated paperwork; and (3) also applied for the reimbursement at the originating dealership in the language of that dealership (e.g. French or Flemish if purchased in Belgium). Deciding on the set of restrictions garnering the highest expected profit presumably involved the expense of lawyers and economic consultants. Ultimately, the European Commission stopped FIAT and other European automobile manufacturers from deterring arbitrage in this manner.

The models I develop are applicable to these and other cases of arbitrage deterrence. In Section 2, I incorporate into the standard model of third-degree price discrimination the opportunity for the monopolist to deter arbitrage by distorting the two prices and, additionally, by raising consumer arbitrage costs. In Section 3, I extend my analysis of arbitrage deterrence to the international market in prescription drugs. In that market, prices in the foreign market are negotiated while domestic prices are set by the firm. Section 4 concludes the paper.

2 Spending to Deter Arbitrage When the Monopolist Sets the Price in Both Markets

2.1 Notation and Assumptions

Consider a monopolist selling in two markets (denoted U and N). The price in market i is denoted p_i, the induced demand (in the absence of any arbitrage) is denoted $D_i(p_i)$, and the constant per-unit production cost is denoted c. Denote the manufacturer's exogenous profit function in market i as $\pi_i(p_i) = (p_i - c)D_i(p_i)$ for $i = U, N$. Assume each profit function (π_i) is strictly concave, differentiable and single-peaked. Denote the global maximizer of each function as $p_i^m = \text{argmax}_{p_i \geq 0}\pi_i(p_i)$, for $i = U, N$. I make the conventional assumption that, at any common price $p > 0$, $\pi_U'(p) > \pi_N'(p)$. Hence, the monopolist would set a higher price in market U than in market N in the absence of the threat of arbitrage. As I will show, under threat of arbitrage the firm will narrow this price differential. Henceforth, I sometimes refer to U as the high-price market and N as the low-price market.

Assume $\Delta_0 \geq 0$ is an exogenous price differential beyond which arbitrage would occur. Δ_0 reflects inherent difficulties consumers in the high-price market (U) may have in ordering from the low-price market (N) in the absence of firm spending to deter arbitrage. To illustrate with the three applications, if the price differential were Δ_0 or less, no American would take the trouble to fill a prescription at an online pharmacy licensed abroad, no dentist would seek out industrial plastic to make dentures, and no British resident would travel to Belgium to buy a FIAT. At a larger price differential, these activities would occur—unless actively deterred by the firm.

Assume that the manufacturer can raise the consumers' cost of arbitrage to Δ ($\Delta > \Delta_0$). To revert to the three examples, the firm can either launch a campaign focused on scaring buyers in the high-price market away from making purchases in the low-price market or impose restrictions on ancillary services that affect buyers from the high-price market but only if they purchase the good in the low-price market. Engaging in such deterrence tactics is not without its costs.

Denote the cost to the firm of raising the arbitrage threshold to Δ as $K(\Delta - \Delta_0; \alpha)$,

where α is an exogenous shift parameter. Assume K is twice differentiable and that $K(0; \alpha) = 0$. For $\Delta - \Delta_0 > 0$, assume that $K_1(\Delta - \Delta_0; \alpha) > 0$, and $K_{11}(\Delta - \Delta_0; \alpha) > 0$. That is, the firm's marginal cost of raising Δ is strictly positive and strictly increasing. Assume that this marginal cost is strictly increasing in the exogenous shift parameter, α: $K_{12}(\Delta - \Delta_0; \alpha) > 0$, for $\Delta - \Delta_0 > 0$.[3] Finally, I assume that $\pi'_U(0) > K_1(0, \alpha)$ for any α. This is a necessary condition for the firm to spend on arbitrage deterrence.

2.2 Arbitrage Deterrence under Third-Degree Price Discrimination

The monopolist seeks to maximize:

$$\max_{p_U, p_N, \Delta} \pi_U(p_U) + \pi_N(p_N) - K(\Delta - \Delta_0; \alpha) \tag{1}$$

subject to:

$$p_N + \Delta - p_U \geq 0 \tag{2}$$
$$\Delta - \Delta_0 \geq 0. \tag{3}$$

Inequality constraint (2), which is also adopted in Ganslandt and Maskus (2004) and Anderson and Ginsburgh (1999), eliminates from consideration choices known to be suboptimal and hence simplifies the analysis without altering its conclusions.[4]

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[3]Although I assume for simplicity that consumers in market U all have the same arbitrage threshold, it is easy to generalize to the case where consumers have different thresholds. Suppose consumers in market U have one of n distinct baseline arbitrage costs Δ_0^i indexed so that $0 \leq \Delta_0^1 < \Delta_0^2 \ldots < \Delta_0^n$. Assume the manufacturer knows the fraction $f_i \in (0, 1)$ of consumers in each group, where $\sum_{i=1}^{n} f_i = 1$. Assume at cost $K(b; \alpha)$ the monopolist could choose b and raise group i's threshold to $b + \Delta_0^i$ for $i = 1, \ldots, n$ Then provisionally assume for each $i \in (1, \ldots, n)$ that i is the marginally deterred group for which $p_U - p_N = \Delta_0^i$. Choose b, p_U, and p_N as in the text, calculate the maximized profit if i is this borderline group, and then determine which of the previously calculated candidates for the borderline group is the most profitable.

[4]Consider any solution that violates inequality (2). Then $p_U - p_N > \Delta$ for $\Delta \geq \Delta_0$. In that case, no purchases would occur in market U and demand in market N will be $D_N(p_N) + D_U(p_N + \Delta)$. As long as p_U strictly exceeds the cost of purchasing the product in market N, reducing p_U will not alter the firm's net profit since no sales would occur at p_U. However, when p_U is lowered enough that $p_U - p_N = \Delta$, arbitrage will cease, sales in market N will jump down by $D_U(p_N + \Delta)$, and sales

Associate the multiplier $\lambda \geq 0$ with inequality (2) and the multiplier $\gamma \geq 0$ with inequality (3). The solution to the following Kuhn-Tucker conditions is unique and determines the global optimum:

$$\pi'_N(p_N) + \lambda = 0 \tag{4}$$

$$\pi'_U(p_U) - \lambda = 0 \tag{5}$$

$$-K_1(\Delta - \Delta_0; \alpha) + \lambda + \gamma = 0 \tag{6}$$

$$\lambda \geq 0, p_N + \Delta - p_U \geq 0, \text{with complementary slackness} \tag{7}$$

$$\gamma \geq 0, \Delta - \Delta_0 \geq 0, \text{with complementary slackness.} \tag{8}$$

The qualitative characteristics of the endogenous solution to the Kuhn-Tucker conditions depend on the exogenous arbitrage cost (denoted Δ_0). If Δ_0 is sufficiently high, the optimum has the characteristics first described by Robinson (1933). The firm can choose profit-maximizing prices in each market without any concern about arbitrage. In this case, the markets are unconnected so a disturbance in one market like a demand shift will not affect the other market. I refer to this region as R1.

The other two regions, on the other hand, are connected so a shift in one market's demand would affect both markets. If Δ_0 is in an intermediate region, the optimum has the characteristics first described by Anderson and Ginsburgh (1999). I refer to this region as R2. In R2, the firm deters arbitrage by distorting prices but spends nothing to raise the consumer arbitrage cost ($\Delta - \Delta_0 = 0$).

If Δ_0 is sufficiently low, however, the firm not only distorts prices but also spends money to raise the consumers' cost of arbitrage. Only this third region is consistent with the spending on arbitrage deterrence discussed in the introduction. I refer to this third region as R3.

In R1, the exogenous arbitrage cost is high: $\Delta_0 \geq p_U^m - p_N^m$. For any Δ_0 in this region, $\lambda = 0$, the two prices are set at their respective monopoly levels ($p_i = p_i^m$, $i = U, N$) and $\gamma = K_1(0; \alpha)$.

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in market U will jump up by the same amount, raising the firm's gross revenue per unit sold by $p_U - p_N = \Delta > 0$ per unit and leaving production cost unchanged. Hence, no solution violating (2) can be optimal, and requiring that (2) hold eliminates only suboptimal solutions.

In R2, the exogenous arbitrage cost is in an intermediate range: $\Delta_0 \in (\Delta_0^*, p_U^m - p_N^m)$, where $p_U = p^*$ and $\Delta_0^* = p_U - p_N$ are defined implicitly by the following pair of equations:

$$\pi_U'(p_U) + \pi_N'(p_U - \Delta_0^*) = 0 \tag{9}$$

$$\pi_U'(p_U) - K_1(0; \alpha) = 0. \tag{10}$$

Equation (10) defines $p*$ (although $p^*(\alpha)$ depends on α, I suppress this dependence in the notation when emphasizing the dependence is unnecessary). The assumption that $\pi_U'(0) > K_1(0, \alpha)$ ensures that $p^* > 0$.

In the interior of R2, $\pi_U'(p_U) > 0$ and $\pi_N'(p_N) < 0$, implying $p_U < p_U^m$ and $p_N > p_N^m$. Throughout this region, $\lambda > 0, p_U - p_N = \Delta$, and $\Delta = \Delta_0$. As Δ_0 is reduced within this region, λ increases and γ decreases, with their sum remaining $K_1(0; \alpha)$. As Δ_0 decreases, the lower price (p_N) rises, and the higher price (p_U) falls until $\Delta_0 = \Delta_0^*, \gamma = 0.$[5] As p_U falls, the marginal value ($\pi_U'(p_U)$) of increasing it rises until it becomes profitable to supplement the price distortion with spending to raise the cost of arbitrage.[6]

In R3, the exogenous arbitrage cost is low: $\Delta_0 \in [0, \Delta_0^*]$. Throughout this region, $\gamma = 0, p_U - p_N = \Delta$, and $\Delta > \Delta_0$. As Δ_0 is reduced within this region, λ continues to increase, the low price (p_N) continues to rise, the high price (p_U) continues to fall, and hence their difference (Δ) continues to narrow. Even at $\Delta_0 = 0$, however, the two prices will differ ($p_U - p_N = \Delta > \Delta_0 = 0$)

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[5]Without further restrictions, the marginal cost of deterring arbitrage may be so high that when $\Delta_0 = 0$ there would still be no incentive to spend money to raise the consumers' arbitrage cost and R3 would not exist. To ensure its existence, I assume that $K_1(0; \alpha) < \pi_U'(p_U)$ where $\Delta_0 = 0$ and p_U implicitly solves $\pi_U'(p_U) + \pi_N'(p_U - \Delta_0) = 0$, which implies $\pi_U'(p_U) > 0$. This assumption ensures that a firm setting a single price across the two markets because $\Delta = \Delta_0 = 0$ can never be optimizing. For then, the firm would always find it more profitable to raise Δ and p_U locally while keeping p_N fixed since $\frac{d}{dp_U}\{\pi_U(p_U) - K(p_U - p_N - \Delta_0; \alpha)\} > 0$.

[6]To verify that it is never optimal to spend to deter arbitrage without first distorting prices, note that $p_U = p_U^m, p_N = p_N^m$, and $\Delta > \Delta_0$ can never satisfy the conditions necessary for the optimum since (5) implies that $\lambda = 0$, (8) implies that $\gamma = 0$ and hence (6) implies that $-K_1(\Delta - \Delta_0; \alpha) = 0$. But this last equation violates the assumptions about K since $K_1 > 0$ for any $\Delta > \Delta_0$. Intuitively, at $p_U = p_U^m, p_N = p_N^m, \Delta > \Delta_0$ the derivative of $\pi(p_U) - K(p_U - p_N - \Delta_0; \alpha)$ is strictly negative since $\pi_U'(p_U^m) = 0$. Therefore, reducing p_U while holding p_N constant is both feasible and profitable.

Since throughout R3 $\gamma = 0$ and $\lambda > 0$, (4)-(8):

$$\pi'_U(p_U) + \pi'_N(p_U - \Delta) = 0 \tag{11}$$

$$\pi'_U(p_U) - K_1(\Delta - \Delta_0; \alpha) = 0. \tag{12}$$

Intuitively, if the left-hand side of (11) is strictly positive (respectively, negative), the monopolist could maintain Δ and strictly increase profit by strictly increasing (respectively, decreasing) both prices marginally by the same amount. Similarly, if the left-hand side of (12) is strictly positive (respectively, negative), the monopolist could strictly increase profit by maintaining p_N but strictly increasing (respectively, decreasing) Δ and p_U marginally by the same amount. Hence, each equation must hold if the monopolist is maximizing profit.

In Figure 1, the previous discussion is summarized. The two multipliers are depicted as functions of Δ_0 in each of the three regions. To avoid clutter, the behavior of the three decision variables described above are not depicted but are easily reconstructed from (4)-(8).

Since each firm in the three motivating examples not only distorts its prices but also spends money ($\Delta > 0$) to deter arbitrage, only R3 is relevant in these cases. Use of this second instrument to deter arbitrage has both positive and normative effects.

Proposition 1. Positive and Normative Effects of Using a Second Instrument to Deter Arbitrage

Suppose Δ_0 is in R3 and the firm no longer has to rely solely on pricing to deter arbitrage but now can spend to raise the consumers' arbitrage cost ($\Delta > \Delta_0$). In response, it will raise its higher price and lower its lower price. Firm profits will increase but, if its aggregate sales do not increase, social welfare will fall.[7] Consequently, the consumers must lose more than the firm gains.

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[7]In models without arbitrage deterrence, it is well-known that *aggregate* sales are the same under single-price monopoly and price discrimination if both demand curves are linear. A similar result holds in the model if Δ changes and the two demand curves are linear. To see this, let $Q = D_U(p_U) + D_N(p_N)$. Then, $\frac{dQ}{d\Delta} = D'_U(\frac{dp_U}{d\Delta}) + D'_N(\frac{dp_N}{d\Delta})$, where the terms in the two parentheses are derived in the proof of Proposition 1. By definition, $\pi_i = (p_i - c)D_i(p_i)$ for $i = U, N$. Hence, $\pi''_i = 2D'_i$ in the case of linear demands ($D''_i = 0$). Substituting, $\frac{dQ}{d\Delta} = D'_U(\frac{2D'_N}{2D'_N + 2D'_U}) + D'_N(\frac{-2D'_U}{2D_U + 2D'_N}) = 0$.
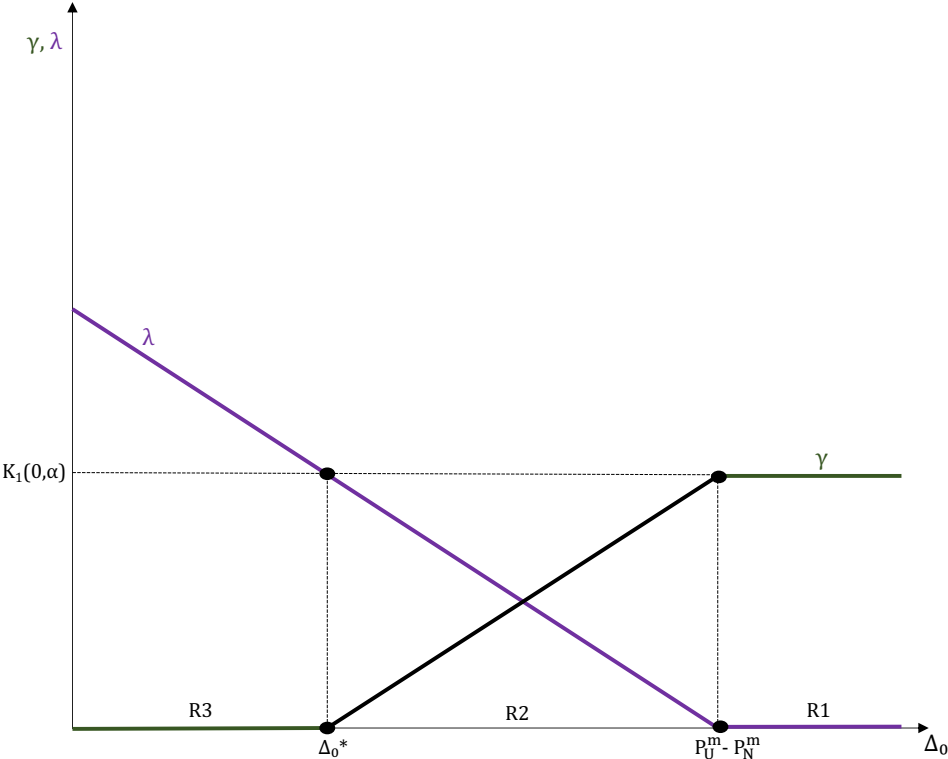
Figure 1: Multipliers in the Three Regions Determined by Δ_0

Proof. The firm chooses its price in market U to maximize $\pi_U(p_U) + \pi_N(p_U - \Delta)$ for a given Δ ($\Delta = \Delta_0$ initially and $\Delta > \Delta_0$ afterwards). Hence, the firm sets p_U to solve $\pi'_U(p_U) + \pi'_N(p_U - \Delta) = 0$. Since $\frac{dp_U}{d\Delta} = \frac{\pi''_N}{\pi''_N + \pi''_U} \in (0,1)$ and $\frac{dp_N}{d\Delta} = \frac{dp_U}{d\Delta} - 1 = -\frac{\pi''_U}{\pi''_N + \pi''_U} < 0$, the increase in Δ above Δ_0 will raise p_U and lower p_N. Since the firm alters its behavior when the second instrument to deter arbitrage becomes available, its profits must strictly increase. Let the superscripts 0 and 1 denote variables before and after the firm spends to deter arbitrage. Let W denote social surplus, and D_i denote quantity sold in market i (for $i = U, N$). Then, since $-K(\Delta - \Delta_0; \alpha)$ is strictly concave in its first argument, I can adapt inequality (16) in Varian (1989) to derive an upper bound on the welfare change:

$$(p_U^0 - c)(D_U^1 - D_U^0 + D_N^1 - D_N^0) - \Delta^0(D_N^1 - D_N^0) - K_1 \cdot (\Delta^1 - \Delta^0) \ \geq \ W^1 - W^0 \tag{13}$$

Each of the three terms on the left is strictly negative: the first because (by assumption) aggregate sales weakly decrease, the second because p_N decreases, and the third because $\Delta > \Delta_0$. Hence when the firm can spend to deter arbitrage rather than having to rely solely on limit pricing, welfare must strictly decrease. In order for total welfare to fall, consumers must lose more in net surplus than the firm gains in net profit. $\square$

The government can counter the firm's efforts to raise the consumers' cost of arbitrage by exogenously raising α. I conclude this section by deducing the effects of such a policy.

Proposition 2. Effects of Increased Regulation When Firm Sets Both Prices

Suppose Δ_0 is in R3. If the government increases α, the monopolist will (a) lower the cost of consumer arbitrage (Δ); (b) lower the higher price (p_U) and raise the lower price (p_N); and (c) continue to deter arbitrage.

Proof. (a) and (b) follow by differentiating (11) and (12) with respect to α to obtain $\frac{dp_U}{d\alpha} = \frac{K_{12}\pi''_N}{\Psi} < 0$ and $\frac{d\Delta}{d\alpha} = \frac{K_{12}(\pi''_U + \pi''_N)}{\Psi} < 0$ where $\Psi = \pi''_N \pi''_U - K_{11}(\pi''_U + \pi''_N) > 0$. Hence, $\frac{dp_N}{d\alpha} = \frac{-K_{12}\pi''_N}{\Psi} > 0$. (c) follows since Δ_0 is assumed to lie in the interior of region R3.

$\square$

3 Arbitrage Deterrence When the Lower Price Is Set by Bargaining: The Branded Pharmaceutical Application

3.1 Spending to Deter Shopping for the Lowest Price

Pecorino (2002) and Dubois et al. (2021) have modified the standard model of price discrimination to take into account the fact that the prescription drug prices in the low-price market N are not set by the firm itself but by negotiations with foreign governments. However, each paper interprets the absence of arbitrage as meaning that the two markets are independent. In this section I show how to extend their analyses when the firm deters arbitrage.

In the case of Böem and Haas, internal memos praising the proposed use of arsenic or lead contamination in the industrial product to eliminate the "bootlegger problem" left no doubt about the company's intentions. While no such memos have surfaced so far in the case of drug manufacturers, there is compelling evidence of efforts and expenditures to scare Americans away from low-price medications in the guise of protecting them from unsafe drugs. In an article artfully titled "Drug Makers Cry 'Danger' Over Imports," the *Wall Street Journal* noted "Drug-company profits are threatened as more Americans buy their medicines from cheaper markets, particularly Canada." (Hensley, 2003).

In fact, filling prescriptions at pharmacies licensed in other high-income countries is as safe as filling them at home. As Michael Law, holder of the Canada Research Chair in Access to Medications dryly observed: "People aren't dying in the streets of Canada from unsafe medications" (Elgin, 2019). Nor, he might have added, are they dying in the streets of other high-income countries.

Ordering online (whether from domestic or foreign pharmacies) does pose additional risks since dangerous counterfeit and adulterated medications are unquestionably sold on the internet.

But reliable services such as PharmacyChecker provide consumers with information about safe online pharmacies licensed in other high-income countries. Research

shows that ordering online from such pharmacies is safe.[8] Bate et al. (NBER 2013) established through random sampling that drugs purchased online from foreign pharmacies certified safe by PharmacyChecker are just as safe as drugs purchased from domestic, brick-and-mortar pharmacies.[9] Furthermore, the FDA has never reported a death or serious adverse reaction suffered by any patient who used a valid prescription to import medication from a foreign pharmacy licensed in another high-income country.

Under most circumstances, importing prescription drugs for personal use is technically illegal, but federal law calls on the FDA to permit such imports through enforcement discretion, and no one has ever been prosecuted for such imports (Freed et al., 2021). In addition, two bills pending in the Senate may remove any remaining ambiguity about the legal status of imports for personal use.[10]

According to the *Wall Street Journal* (Hensley, 2003), the trade organization Pharmaceutical Research and Manufacturers of America (PhRMA) hired a public relations

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[8]International online transactions are often facilitated by physician "co-signing." A doctor in the foreign country, after reviewing the patient's US prescription and either consulting with the prescribing doctor in the US or reviewing the patient's medical file, writes a new prescription just as he would if the US patient had visited his doctor's office. Since the same diseases occur everywhere and are treated with the same medications, this practice can typically circumvent manufacturer attempts to limit arbitrage by changes in presentation (pill vs. capsule, blue tablet vs. red tablet, etc.).

[9]To detect counterfeits, Bate et al. used Raman spectrometry (Witkowski 2005), one of the techniques the FDA uses to distinguish *bona fide* medicine from counterfeits and adulterated pharmaceutical products. Bate (2019) describes his use of Raman spectrometry in more detail.

[10]"The Safe and Affordable Drugs from Canada Act of 2021" (S. 259), introduced by Senator Klobuchar on February 4, 2021, explicitly requires that imports from Canada be allowed if the dispensing pharmacy is licensed in Canada and provides the medication using a valid prescription from a physician licensed in any US state. "The Affordable and Safe Prescription Drug Importation Act" (S.920), introduced by Senator Bernie Sanders on March 23, 2021, is more sweeping. It allows individuals to use a licensed foreign pharmacy in *any* country to fill a US-issued prescription for personal use (up to a 90 day supply), requires the Department of Health and Human Services (HHS) to issue regulations that permit *commercial* importation from Canada and, at HHS's discretion after a two year delay, to permit commercial importation from the *OECD* and other countries. *Commercial* importation (e.g. by Amazon, CVS, etc.) is currently strictly prohibited. For more on commercial arbitrage, see the discussion of Figure 2 in Salant (2023). Finally, Senator Sanders' bill imposes criminal penalties for websites that sell counterfeit drugs or dispense drugs without a required prescription.

firm, Edelman, "to help develop a communications campaign that would dissuade Americans from importing prescription medicines." In deciding whether to (1) emphasize the questionable legal status of importation for own use or (2) emphasize safety issues to determine what mattered more to people without drug-insurance coverage, Edelman consulted focus groups. In 2003, Edelman concluded that safety, not legality, was the central concern of such individuals when deciding whether to import their prescription drugs to save money. According to Edelman's report "Fear and accountability 'move the needle' of consumer perceptions the most." (Hensley, 2003).

Therefore, drug manufacturers, through PhRMA and seemingly independent, grass-roots organizations that are funded by drug manufacturers, have spent millions of dollars warning that imported pharmaceuticals are dangerous because they may be counterfeits.[11] Since safety is not a legitimate concern when importing from pharmacies licensed in high-income countries, the manufacturers have always avoided distinguishing these safe pharmacies from potentially unsafe ones.

Through their proxy organizations, the manufacturers' treatment of Pharmacy-Checker, an organization dedicated to providing objective information that helps Americans import prescription drugs safely, reveals the producers' true concern about imports. Instead of welcoming PharmacyChecker's efforts, the manufacturers have tried at considerable expense to drive it off the internet and out of business.[12]

Finally, the manufacturers have spent tens of millions of dollars lobbying Congress and paying "user fees" to the FDA. The stated purpose of such fees is to expedite drug approval. According to Jewett (2022) in the *New York Times* "The pharmaceutical industry funding alone has become so dominant that last year it accounted for *three-quarters*—or $1.1 billion—of the agency's drug division budget." Dr. Joseph Ross, an authority on FDA policies at Yale School of Medicine, said that user's fees are "kind of like a devil's bargain . . . because it turns this every-five-year cycle into the

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[11]According to Elgin (2019) one such "astroturf" organization, Partnership for Safe Medicines (PSM), was actually run from 2005 to 2017 by executives who simultaneously worked for PhRMA; moreover paychecks of consultants to PSM came directly from PhRMA.

[12]For a discussion of the tactics used by "a network of other groups closely aligned with US pharmaceutical companies . . . to drive PharmacyChecker off the internet" see Stoltz (2019). For a more recent account of PharmacyChecker's costly legal battles, see Botkin (2022).

FDA essentially asking industry, 'What can we do to secure this money?'" Even the FDA commissioner, Dr. Robert Califf, has expressed concern about these payments: "Philosophically, I wish the taxpayer paid for all the FDA and there weren't user fees." Perhaps concern about the loss of this financial support explains the FDA's apparent reluctance to declare as safe imports from pharmacies licensed in high-income countries. According to Jewett (2022), Senator Sanders "suggested that the pharmaceutical companies' tendency to charge 'outrageous' prices was related to their significant role in funding and advancing policy goals of the FDA's drug division."

Suffice it to say that if manufacturers were concerned only about the safety of imported prescription drugs, they would clearly distinguish between dangerous online pharmacies and those licensed in high-income countries instead of conflating the two.

I now show how to adapt models of the international drug market where the foreign price is negotiated but the two markets are independent to the case where the firm tailors its pricing and spending to deter Americans from purchasing in the low-price market and, as a result, the two markets are linked. In the pharmaceutical application, I refer to market U as the US (or domestic) market and market N as the foreign (or negotiated) market.

I envision the negotiation and profit maximization as occurring simultaneously. The firm has a marketing specialist who sets the domestic price and an expert in the intricacies of European regulations who bargains with the foreign government's negotiator about p_N. Both firm employees seek to maximize the firm's profit but these very different responsibilities have been delegated to different individuals who do not confer.[13] The firm's price-setter has a conjecture about p_N, denoted $\tilde{p}_N$ and chooses the domestic price and the cost of arbitrage (p_U, Δ). The foreign government's negotiator has conjectures, denoted $\tilde{p}_U, \tilde{\Delta}$, and reaches agreement with the firm's European expert on p_N. In equilibrium, the conjectures are correct. The result is a triple of numbers $(p_N^e; p_U^e, \Delta^e)$ with the property that the last two variables maximize the firm's profit given a correct conjecture about the negotiated foreign price and that price solves the Nash Bargaining problem given correct conjectures about the firm's domestic price

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[13]Delegation seems plausible in this context. In some cases, delegation increases firm profits (Baye et al., 1996).

and the consumers' cost of arbitrage.[14]

3.2 The Firm's Problem

The price-setter seeks to maximize:

$$\max_{p_U, \Delta} \pi_U(p_U) + \pi_N(\tilde{p}_N) - K(\Delta - \Delta_0; \alpha) \tag{14}$$

subject to:

$$\tilde{p}_N + \Delta - p_U \geq 0 \tag{15}$$
$$\Delta - \Delta_0 \geq 0. \tag{16}$$

The price setter's profit-maximizing choices depend on its conjecture, $\tilde{p}_N$ as well as on the exogenous parameters. This conjecture can lie in one of two regions. In one (explored by Anderson and Ginsburgh, 1999), the firm deters arbitrage by adjusting its domestic price but without spending anything to increase the consumer arbitrage threshold: $\Delta - \Delta_0 = 0$. In the other, the firm in addition spends money to deter arbitrage: $\Delta - \Delta_0 > 0$. Throughout Section 3, I assume that Δ_0 is fixed and satisfies $\pi'_U(\Delta_0) > K_1(0; \alpha)$.[15] This assumption insures the existence of an interval of strictly positive conjectured foreign prices low enough for there to be a region where the firm spends money to deter arbitrage.

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[14]Each of the monopoly models has its monopsony counterpart. Consider, for example, the model where one price is set by bargaining. Suppose a monopsonist sells at a fixed price per unit its production, which is proportional to the aggregate input from its two plants. For concreteness, assume this input is labor. Suppose some labor is employed in a northern plant and the remainder is employed in a southern plant. In each plant, the supply of labor is larger when the wage is higher. The firm sets the wage in the southern plant but negotiates the northern wage with a representative of the northern workers. If the northern wage is sufficiently higher than the southern wage, workers would want to migrate north. Such a migration would leave aggregate output and revenue unchanged, but the firm's costs would rise more in the northern plant than they would fall in the southern plant. To avoid this loss in profits, the firm would narrow the wage differential and, in addition, might spend money to deter migration.

[15]This inequality is equivalent to $\pi'_U(\tilde{p}_N + \Delta) > K_1(\Delta - \Delta_0; \alpha)$ for $\Delta = \Delta_0$ and $\tilde{p}_N = 0$. The inequality is thus sufficient for the firm to spend to deter arbitrage if $\tilde{p}_N$ is sufficiently low.

Throughout the region where $\Delta = \Delta_0$, $p_U = \tilde{p}_N + \Delta_0$. Thus, p_U is a linear function of the conjectured foreign price with a constant slope of +1. The lower the conjectured foreign price, the lower is p_U and the higher is $\pi'_U(p_U)$. The firm chooses $p_U = p^*$ when the conjectured foreign price is $\tilde{p}_N = p^* - \Delta_0$.

In the region where $\Delta > \Delta_0$, the domestic price is implicitly defined as the solution to $\pi'_U(p_U) = K_1(p_U - \tilde{p}_N - \Delta_0; \alpha)$. Denote this solution as $p^*_U(\tilde{p}_N; \alpha)$. It is straightforward to verify that the optimal domestic price in this region is increasing in the conjectured foreign price with a slope that is less than +1. Differentiating, I obtain $\pi''_U dp_U = K_{11} dp_U - K_{11} d\tilde{p}_N + K_2 d\alpha$. Hence $\frac{dp_U}{d\tilde{p}_N} = \frac{-K_{11}}{\pi''_U - K_{11}} \in [0, 1)$. The arbitrage threshold in this region is $\Delta = p^*_U(\tilde{p}_N; \alpha) - \tilde{p}_N$. Therefore, $\frac{d\Delta}{d\tilde{p}_N} = \frac{-\pi''_U}{\pi''_U - K_{11}} \in [-1, 0)$. The threshold is strictly decreasing with a slope weakly greater than -1.

These results are summarized below:

$$p_U = \begin{cases} p^*_U(\tilde{p}_N; \alpha) & \text{for } \tilde{p}_N \in [0, p^* - \Delta_0) \\ \tilde{p}_N + \Delta_0 & \text{for } \tilde{p}_N \in [p^* - \Delta_0, p^m_U - \Delta_0] \end{cases} \tag{17}$$

and

$$\Delta = \begin{cases} p^*_U(\tilde{p}_N; \alpha) - \tilde{p}_N & \text{for } \tilde{p}_N \in [0, p^* - \Delta_0) \\ \Delta_0 & \text{for } \tilde{p}_N \in [p^* - \Delta_0, p^m_U - \Delta_0] \end{cases} \tag{18}$$

The two panels of Figure 2 depict the firm's profit-maximizing choices as a function of its conjecture ($\tilde{p}_N$).

Consider the case where the cost of deterrence is linear in Δ: $K(\Delta - \Delta_0; \alpha) = k(\alpha) \cdot (\Delta - \Delta_0))$. In this case, the maximand in (14) is quasilinear. To conform to the restrictions imposed previously on $K(\cdot)$, assume $k(\alpha) > 0$ and $k'(\alpha) > 0$. In the quasilinear case, $K_{11} = \frac{d}{d\Delta} k(\alpha) = 0$. Hence, $\frac{dp^*_U}{d\tilde{p}_N} = \frac{-K_{11}}{\pi''_U - K_{11}} = 0$, $p^*_U = p^*$, $\Delta > \Delta_0$ and $\Delta^* = p^*_U(\tilde{p}_N; \alpha) - \tilde{p}_N = p^* - \tilde{p}_N$. In terms of Figure 2, the upward-sloping segment of $p^*_U(\tilde{p}_N, \alpha)$ is replaced by a horizontal line of height p^* and $\Delta(\tilde{p}_N) = p^* - \tilde{p}_N$, a decreasing line of slope $= -1$.

Since $k'(\alpha) > 0$ and $\pi'_U(p_U) = k(\alpha)$ the horizontal line shifts down if α is increased exogenously and the decreasing line of slope -1 shifts down.

P_U

$P_U = \tilde{P}_N + \Delta_0$

$P^*(\alpha)$

$P^*(\alpha) - \Delta_0$ $P_U^m - \Delta_0$ $\tilde{P}_N$
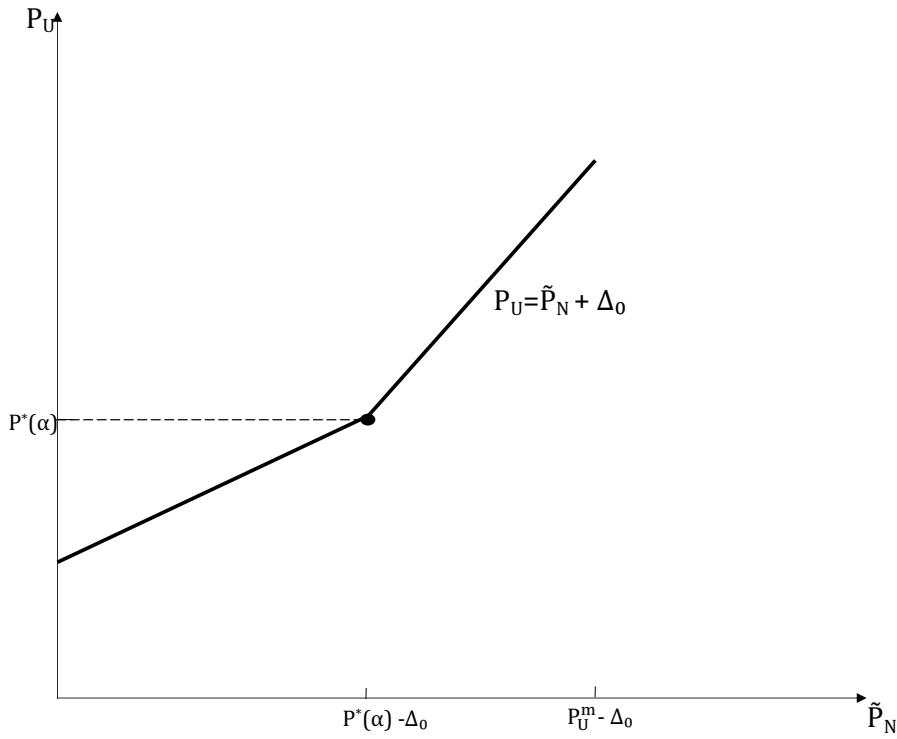
(a) Domestic Price as a Function of Conjectured Foreign Price

Δ

$\Delta = P_U^*(\tilde{P}_N; \alpha) - \tilde{P}_N$

Δ_0

$P^*(\alpha) - \Delta_0$ $P_U^m - \Delta_0$ $\tilde{P}_N$

19
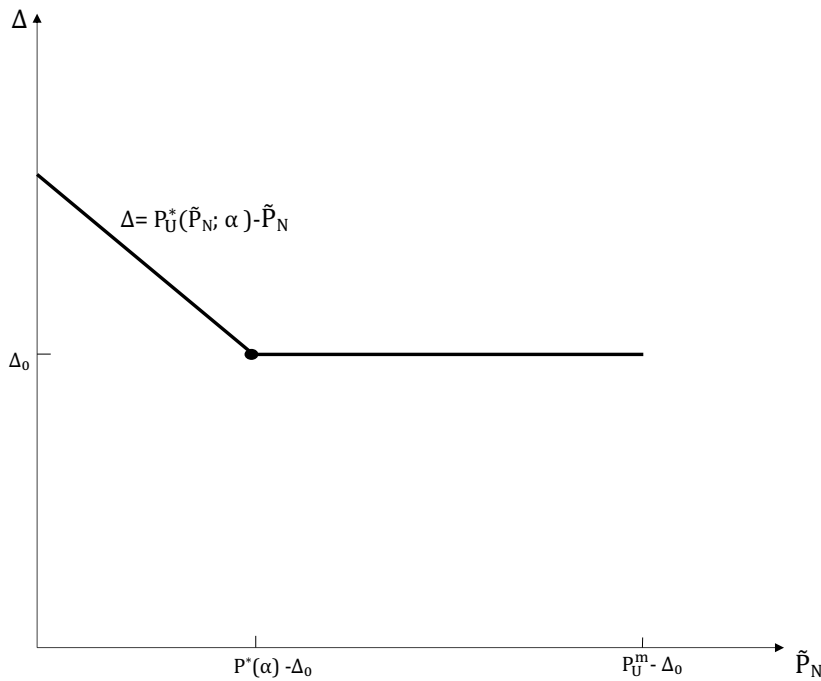
(b) Cost of Consumer Arbitrage as a Function of Conjectured Foreign Price

3.3 The Bargaining Problem

The foreign price is assumed to solve the Nash Bargaining problem. Like Pecorino (2002) and Dubois et al. (2021), I assume that if bargaining breaks down, the foreign government buys from another source at a higher exogenous price (denoted p_A) so that the surplus the foreign government receives from a successful bargain is $\int_{p_N}^{\infty} D_N(x)dx - \int_{p_A}^{\infty} D_N(x)dx = \int_{p_N}^{p_A} D_N(x)dx$. I also assume that if bargaining breaks down, the monopolist loses the foreign market but would still sell in the US market and at the monopoly price.

It is assumed that the foreign price (p_N) emerging from the negotiations maximizes the Nash product. The negotiator is assumed to hold fixed conjectures about the domestic price and cost of arbitrage chosen by the firm ($\tilde{p}_U$ and $\tilde{\Delta}$):

$$\max_{p_A \geq p_N \geq c} \left(\int_{p_N}^{p_A} D_N(x)dx \right)^{\theta} \left(\pi_N(p_N) + \pi_U(\tilde{p}_U) - K(\tilde{\Delta} - \Delta_0; \alpha) - \pi_U(p_U^m) \right)^{1-\theta} \quad (19)$$

where θ denotes the bargaining power of the negotiator and $1 - \theta$ denotes the bargaining power of the firm. Note that if $\theta = 0$, the firm has all the bargaining power and the objective function is maximized at $p_N = p_N^m$ regardless of the conjectures ($\tilde{p}_U$ and $\tilde{\Delta}$).

At an interior optimum, the negotiated p_N must satisfy the following first-order condition:

$$\left(\frac{\theta}{1-\theta} \right) \left(\frac{\pi_N(p_N) + \pi_U(\tilde{p}_U) - K(\tilde{\Delta} - \Delta_0; \alpha) - \pi_U(p_U^m)}{\int_{p_N}^{p_A} D_N(x)dx} \right) = \frac{\pi_N'(p_N)}{D_N(p_N)}. \quad (20)$$

3.4 Equilibrium, Comparative Statics, and Estimation Bias

In equilibrium, the conjectures are correct. So $\tilde{p}_U = p_U^*(p_N; \alpha)$ and $\tilde{p}_N = p_N$. Hence,

$$\left(\frac{\theta}{1-\theta} \right) \left(\frac{\pi_N(p_N) + \pi_U \left(p_U^*(p_N; \alpha) \right) - K \left(p_U^*(p_N; \alpha) - p_N - \Delta_0; \alpha \right) - \pi_U(p_U^m)}{\int_{p_N}^{p_A} D_N(x)dx} \right) = \frac{\pi_N'(p_N)}{D_N(p_N)}. \quad (21)$$

Four properties of equation (21) will prove useful: (1) the first factor on the left is strictly increasing in θ since its numerator increases with θ and its denominator

decreases; (2) the second factor increases with p_N since its numerator increases with p_N and its denominator decreases;[16] (3) the right-hand side of (21) strictly decreases in p_N given a plausible assumption about the curvature of D_N;[17] and finally, (4) the function $p_N(\theta)$ must be downward-sloping since a strict increase in p_N reduces the right-hand side of (21) and raises the second factor on its left-hand side, requiring a decrease in θ to maintain the equality.

Since the left-hand side of (21) strictly increases in p_N and the right-hand side strictly decreases, any interior solution must be unique. I denote the price in market N in the bargaining equilibrium as a function of θ as $p_N^e(\theta; \alpha)$ and plot it in Figure 3. I now consider some economic implications of the equilibrium.

Whenever the government raises α to discourage arbitrage deterrence, the effects are qualitatively the same as in Proposition 1 where the foreign price is set by the firm. More formally,

Proposition 3. Effects of Increased Regulation When Lower Price Is Negotiated
If $\Delta > \Delta_0$, an increase in α causes the foreign price to increase. In the quasilinear case, the increase in α causes the domestic price and the cost of consumer arbitrage to decrease.[18]

Proof. If the government raises α, the second factor on the left-hand side of (21) declines. So, for a fixed p_N, θ must increase, reflecting a rightward shift of $p_N^e(\theta; \alpha)$ in Figure 3. To restore θ to its exogenous level, p_N must increase along the shifted function $p_N^e(\theta; \alpha)$.

In the quasilinear case, $p_U^*(p_N, \alpha) = p^*(\alpha)$, which shifts down if α is increased

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[16]To verify that the numerator of the second factor on the left is strictly increasing in p_N, differentiate with respect to p_N to obtain: $\pi_N'(p_N) + \{\pi_U'(p_U^*) - K_1(p_U^* - p_N - \Delta_0; \alpha)\}\frac{dp_U^*}{dp_N} + K_1(p_U^* - p_N - \Delta_0; \alpha) > 0$. To verify that these terms sum to a positive number, note that the first term is strictly positive since (21) could otherwise not hold, the last term (K_1) is strictly positive by assumption, and the term in braces is zero due to the envelope theorem.

[17]It is required that $D_N''(p_N) \leq \frac{D_N^2(p_N)}{D_N(p_N)}$, which will be satisfied by any weakly concave demand curve and some convex ones. To verify that this condition ensures that the right-hand side is strictly decreasing in p_N, differentiate it with respect to p_N and show that the derivative is negative. To do so, substitute out of terms involving π_N and its derivatives, using the definition $\pi_N = (p_N - c)D_N(p_N)$ and then assume the condition for D_N'' holds.

[18]Quasilinearity is sufficient for this result but by no means necessary.
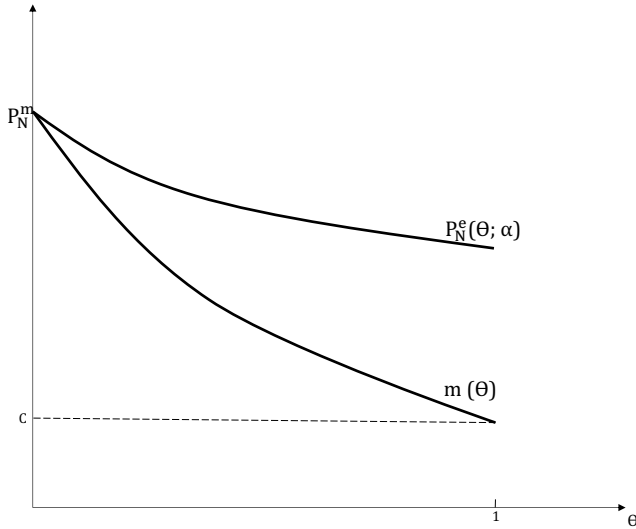
Figure 3: Foreign Price as a Function of Foreign Government's Bargaining Power if Arbitrage Deterrence Is (1) Taken into Account $\left(p_N^e(\theta; \alpha)\right)$ or (2) Ignored $(m(\theta))$.

exogenously. Hence, the lower foreign price (p_N) rises, the higher domestic price (p_U) falls by the same amount, and their difference (Δ) falls. □

Finally, (20) permits identification of an estimation bias that is introduced by the literature's mistaken assumption that the two markets are independent.

Proposition 4. Biased Estimates If Deterrence Is Ignored
Suppose the markets are linked because the firm is deterring arbitrage. Then an analyst who incorrectly assumes that the markets are independent ($p_U = p_U^m, \Delta = \Delta_0$) will always underestimate the negotiator's bargaining power ($\hat{\theta} < \theta$) provided $\theta > 0$.

Proof. If $\theta = 0$, $p_N = p_N^m$ regardless of conjectures about Δ and p_U. If $\theta > 0$ and the econometrician incorrectly assumes that the two markets are independent, then his error will result in an inflated numerator of the second factor on the left of (20) since $\pi_U(p_U^m) > \pi_U(p_U^*(p_N; \alpha))$ and $-K(0; \alpha) \geq -K(\Delta - \Delta_0; \alpha)$. For (20) to hold, the inflated second factor must be offset by a deflated first factor. Hence, an econometrician

observing a given $p_N < p_N^m$ and taking no account of the threat of arbitrage will understate the negotiator's actual bargaining power ($\hat{\theta} < \theta$). □

I denote the foreign price as a function of θ under the mistaken assumption that the markets are independent as $m(\theta)$ and plot it in Figure 3.

Intuitively, there are two forces that elevate the negotiated foreign price: fear of arbitrage and the strength of the firm's bargaining power. If an analyst seeking to explain the observed p_N ignores the first force, he will assign undue importance to the second factor. To take an extreme example, that the foreign government has all the bargaining power ($\theta = 1$). Then, if the markets were independent, the foreign price would be driven down to the per-unit cost (c). Upon observing $p_N > c$, the analyst would attribute the higher price to enhanced firm bargaining power when in fact the higher price reflects arbitrage deterrence.

This section concludes with a comparison of the firm's decisions in the two models.

Proposition 5. Effects of Making the Firm Negotiate the Foreign Price
Suppose θ_0 is in R3 and the firm is setting both prices. If suddenly forced to negotiate the price in market N, the firm will negotiate a lower p_N and will set a lower p_U while raising Δ. Firm profits fall and net consumer surplus rises in both markets.

Proof. Since Δ_0 is in R3, the firm is initially spending to deter arbitrage and must be setting $p_N > p_N^m$. Its choices of p_U and $\Delta(> \Delta_0)$ can be read from Figure 2a and 2b since they would be the same as if the firm anticipated that this p_N had been set by bargaining.

However, the negotiated price must be smaller than p_N^m or the right hand side of (21) would be negative and could not equal the positive left-hand side. So the foreign price must fall. Figure 2a and 2b then imply that Δ strictly rises and p_U weakly falls. Hence, when forced to negotiate, the foreign price will strictly fall, the domestic price will weakly fall, and Δ will strictly rise. Firm profits must fall since when the firm chose the unique profit-maximizing pair of prices, it did not chose these prices although they were feasible. Consumers benefit strictly in the foreign market and weakly in the domestic market because of the price reductions in each market. □

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4 Conclusions

This paper has analyzed situations where the same good is sold in two markets at different prices and yet virtually no buyers from the high-price market take advantage of the savings available in the low-price market. It is typically assumed that exogenous arbitrage costs prevent shopping for the lower price. In such cases, as long as the firm has a constant marginal cost of production, the prices in the two markets will be independent of each other. However, the firm may instead be limit-pricing to deter arbitrage and, if profitable, may in addition be taking actions to make arbitrage more costly. In that case, the two markets become linked despite the absence of any arbitrage between them. The paper has considered historical examples of deliberate arbitrage deterrence from the chemical and automotive industries. The international market in prescription drugs furnishes an important contemporary example. I have incorporated arbitrage deterrence into the standard model of third-degree price discrimination and into a second model where the lower of the two prices is set not by the firm itself but through Nash Bargaining. In the bargaining model, if the absence of arbitrage is mistakenly attributed to exogenous factors when in fact it is the result of deliberate deterrence, econometric estimates of the firm's bargaining power will be biased upward.

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