

Arbitrage Deterrence: A Theory of International Drug Pricing *

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January 3, 2021

Abstract

Prices of patented pharmaceuticals in the United States exceed the prices that foreign governments have negotiated for the same drugs, which in turn exceed the marginal costs of production. This paper provides a tractable theoretical model that explains these stylized facts while taking account of the structure of the industry. The explanation involves arbitrage-deterrence due to oligopolistic limit-pricing: manufacturers would reject proposed foreign prices any closer to the marginal cost of production because the resulting price differentials would trigger massive arbitrage into the higher-priced US market. The model is used to predict the consequences of policies proposed to reduce domestic drug prices, such as (1) ensuring that Medicare pays the price negotiated by foreign governments, (2) legalizing commercial arbitrage, and (3) promoting importation for personal use of prescription drugs from online pharmacies licensed in other high income countries. Tying Medicare prices to prices negotiated by foreign governments will allow these countries to press for even lower prices. Facilitating commercial and personal imports, on the other hand, will raise foreign prices. Therefore, when each policy is set to achieve the same reduction in the domestic retail price, the loss in manufacturer profits is greatest when Medicare's buying power is utilized. A combination of the three policies can leave foreign prices unchanged while lowering the domestic price. Although each of these policies to lower the domestic price will depress innovation in the long run, the government can offset this side-effect. It is shown to be cheaper for the government to restore innovation by subsidizing all research to identify promising molecules once it is in midstream rather than by rewarding only research which proves successful.

*Jim Adams stimulated my interest in this topic, and I am indebted to him for many useful discussions. I also wish to thank Yuan Chen, Yichuan Wang, and Haozhu Wang for their valuable research assistance and Rabah Amir, Andrew Daughety, Gérard Gaudet, Stephen LeRoy, Joshua Linn, Joseph Newhouse, Yesim Orhun, Charles Phelps, Jennifer Reinganum, Anna Schmidt, and Jon Sonstelie for comments on earlier drafts. I am indebted to Gabriel Levitt for clarifying the mechanics of personal arbitrage and for his continuing encouragement. I am particularly grateful to Mingyuan Zhang for his help in both analyzing the model and simulating it and to Marius Schwartz for his extensive comments on a previous draft. Financial support of the Michigan Institute of Teaching and Research in Economics (MITRE) is gratefully acknowledged.

1 Introduction

How to lower the prices of patented pharmaceuticals in the United States without deterring innovation of new drugs (CEA 2018) constitutes a major policy dilemma.¹ Before sensible policy can be devised to resolve this dilemma, it is necessary to understand the determinants of drug innovation and of drug pricing in the United States and abroad.

Any model of the international pharmaceutical market must explain three stylized facts: (1) Americans pay much more than Europeans and others for the same patented drugs, (2) drug prices abroad result from bargaining between drug manufacturers and foreign governments, and (3) even the lower foreign prices vastly exceed the marginal costs of production.

For concreteness, consider the direct-acting antivirals (DAAs) used to treat the hepatitis C virus (HCV). There are four patented drugs, each of which can cure genotypes 1-4. Sovaldi is the oldest and best established.² Americans pay at least \$65,000 to cure their HCV with Sovaldi, while Europeans pay \$40,000, even though the marginal cost of producing this cure is estimated to be less than \$140.³

Berndt (2007) and others have sought to use the traditional model of third-degree price discrimination (Robinson 1933) to explain these facts. While this model does predict that a manufacturer would charge different prices exceeding marginal cost in different markets, it assumes that every price is set by the manufacturer without any negotiation.⁴ Moreover, according to experts on parallel trade in pharmaceuticals within the EU, "... many patients in the United States purchase prescription drugs on a self-pay basis or within tiered co-payment structures [and]... these patients are more sensitive to drug prices than their European counterparts. ..." (Kyle et al., 2008). Given these relative elasticities, the traditional model predicts that the European price should exceed the US price, not the reverse.

The popular explanation for the lower foreign price is that in Europe, Canada, and elsewhere, governments use their considerable bargaining power to get lower prices from manufacturers, whereas no comparable bargaining occurs in the United States. As the Council of Economic Advisers (2018) notes, "Most OECD nations employ price controls in an attempt to constrain the cost of novel biopharmaceutical products, e.g. through cost-effectiveness or reference pricing policies."

But bargaining alone cannot explain the third stylized fact. For, as the Council of Economic Advisers (CEA) goes on to say, "... in price negotiations with manufacturers, foreign governments with centralized pricing exploit the fact that once a drug is already produced, the firm is always better off selling at a price above the marginal cost of production and making a profit, regardless of how small, than not selling at all. *Thus, 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—and firms will continue to sell to that country.*" (CEA 2018, 15; emphasis added).⁵

¹If reducing domestic drug prices does not lower innovation below the socially optimal level, of course, there is no policy dilemma to resolve. For a discussion of why medical innovation may currently exceed the socially optimal level, see Garber et al. (2006).

²The other three are Mavyret, Vosevi, and Epclusa.

³It is widely acknowledged that the prices of drugs under patent in the United States exceed the prices of those same drugs abroad, although admittedly the *magnitude* of this excess is impossible to quantify, given the secret rebates and discounts manufacturers routinely offer their customers.

⁴Malueg and Schwartz (1994) analyze third-degree price discrimination by a monopolist. Their motivation differed from mine since they were motivated by parallel imports to the US from very low income countries.

⁵The academic literature (Grossman and Lai 2008, 386 and Figure 1) also predicts that when re-imports are illegal, governments imposing price controls will bargain down to the marginal cost of production under the plausible assumption that these countries

The data strongly conflict with this prediction of pricing at marginal cost. The prices negotiated by Canada and the governments in Western Europe are sometimes many hundreds of times larger than the marginal costs of production. For example, no price in Western Europe for a 12-week course of the HCV drug Sovaldi is below \$40,000. And yet “a recent study estimated the cost of production of sofosbuvir [Sovaldi] to be U.S. \$68-\$136 for a 12-week course of treatment based on the same manufacturing methods used in the large-scale generic production of HIV/AIDS medicines (Hill et al., 2014), and its findings have not been challenged” (Iyengar et al. 2016). Other treatments for HCV have similar costs of production (Hill et al. 2014).

The real question is not why prices in Western Europe and Canada are so low but why they are so high! They are low relative to US prices, but they are high relative to the marginal costs of production.

The prediction that foreign governments will bargain prices down to the marginal cost of production implicitly assumes that negotiated prices are “unconnected” to prices in the United States.⁶ That prices negotiated in such countries greatly exceed the marginal cost of production, however, strongly suggests that the markets *are* in some way connected. This is no mere academic quibble. For if the markets are connected, making foreigners pay their “fair share” for future drug innovation by forcing up the prices they currently pay for drugs would have the undesirable consequence of driving up US prices as well.

Logically, negotiated prices exceed marginal costs for one of two reasons: either (1) government negotiators have no desire to bargain so aggressively even though manufacturers would accept such demands or (2) government negotiators anticipate that manufacturers would reject demands for prices closer to marginal cost. Egan and Philipson (2013) make the former argument. They contend that foreign governments refrain from bargaining for even lower prices out of fear of depressing future innovation (innovation costs for *current* drugs being sunk). Given that the discovery of promising molecules and their development into drugs takes more than a decade and is fraught with uncertainty, it seems unlikely that foreign governments would refrain from pressing for lower prices on this account. Moreover, Egan and Philipson’s theory cannot explain why big PhRMA spends so lavishly to warn the public about the dangers of foreign imports from pharmacies licensed in other high income countries when such imports constitute a negligible percentage of prescriptions filled in the United States.

A more plausible explanation for why government negotiators do not demand prices closer to marginal cost is that they anticipate drug manufacturers would reject such demands out of fear of arbitrage. Fear of arbitrage also explains the massive spending of big PhRMA to deter imports. Imagine what would happen if Americans seeking medication to cure their hepatitis C continued to be charged tens of thousands of dollars at pharmacies licensed in the United States but were assured that they could safely acquire the same drug from online pharmacies licensed abroad for as little as \$140 (marginal cost). There would be massive arbitrage, but manufacturers would quickly act to block it. Manufacturers would invest heavily in misinforming buyers that it is unsafe to import from *any* foreign pharmacy, and they would simultaneously narrow the difference in prices between the two markets until massive imports ceased.⁷

are not too sizable compared with the region that innovates.

⁶It also assumes that (1) foreign governments propose prices on a take-it-or-leave-it basis and (2) information is assumed to be complete, two assumptions that we adopt as well.

⁷Neither of these tactics could be employed when these manufacturers sought to block pharmaceutical trade within the EU since (1) importing from another EU country is legal and safe and (2) demand within Europe is relatively insensitive to price reductions in the importing country. Since parallel trade within the European Union is legal, these same companies, at considerable cost, have had to devise other strategies to limit the damage massive parallel trade would do to their profits. These include strategic use of

The *threat* of arbitrage is what connects the low-price and high-price markets. As internet shopping expands, the threat that cheaper medicines will be purchased from abroad can only grow in importance. The evidence that manufacturers recognize that massive arbitrage would endanger their profits is the huge sums they spend to prevent it. In the United States, where importing drugs is illegal, manufacturers and the nonprofit “pro-consumer” organizations that manufacturers fund surreptitiously (Kopp and Bluth 2017) lobby Congress to preserve the import ban using the pretext that all pharmaceutical imports from Canada or Western Europe are, without exception, “unsafe.” They have also enlisted the FDA in this disinformation campaign (Levitt 2019).

However, a private firm, PharmacyChecker.com, has developed extensive methods to determine which online foreign pharmacies are safe (Honest Apothecary 2013). Using Raman spectrometry (Witkowski 2005), the same technique that the FDA uses to distinguish bona fide medicine from counterfeits and adulterated pharmaceutical products, Bate et al. (NBER, 2013) conclude that drugs purchased from foreign pharmacies certified safe by PharmacyChecker.com are just as safe as drugs purchased from domestic, brick-and-mortar pharmacies.⁸

If arbitrage were legal and safe, the markets would be perfectly connected and the domestic and foreign prices would coincide. On the other hand, if arbitrage were illegal and regarded as sufficiently unsafe, the foreign negotiated price would fall to marginal cost and the domestic price in the U.S. would rise to the Cournot price.⁹ However, there is an important but neglected intermediate case where reselling drugs is illegal but nonetheless the markets are connected. Banning pharmaceutical imports does not eliminate importation; it merely makes engaging in it more costly. Massive arbitrage would still occur if the price difference were sufficiently great. Our formulation permits consideration not only of the extremes but also of this *intermediate* case where the threat of arbitrage leads manufacturers to reject a negotiated foreign price any closer to the marginal cost of production.

In the equilibrium of this intermediate case, the price differential that emerges is just small enough to deter massive arbitrage. Only inframarginal buyers with unusually low thresholds would still purchase from foreign pharmacies. Recent empirical findings (Hong et al., 2020) are consistent with this prediction: “The findings suggest that patients are not using prescription purchases outside the US to meet their medication needs.” In particular, according to this study based on 61,238 adults taking prescription medicines, a mere 1.5% of US adults purchasing prescription medications bought them abroad to save money.¹⁰ Hence, the pharmaceutical industry’s intensive (and expensive) campaign to scare and confuse potential

marketing authorizations, patents, trademarks, vertical restraints, launch timing, and refusals to supply.

⁸Firm profit, not consumer safety, motivates these lobbying expenditures. As Kesselheim and Choudhry (2008) emphasize, “Concerns about the integrity of imported patented and generic drugs from these markets [Canada and Europe] are often exaggerated, and U.S. regulators should be able to readily ensure the safety of imported products.” According to Outterson (2005), “The most thorough recent analysis . . . concludes that Canadian drug supply is actually safer on balance than that of the United States. . . . The EU has many years of experience with parallel trade in pharmaceuticals, without significant safety issues.” Outterson (2005) points out that the behavior of manufacturers itself reflects a disregard for consumer safety. “By cutting off direct supplies to exporting pharmacies, the pharmaceutical companies force additional intermediaries into the supply chain, which increases safety and handling problems, increases inefficiencies and increases the opportunity for spoilage and introduction of counterfeits. If the concern is truly patient safety, supply restrictions are a crude and counterproductive tool.”

⁹These are essentially the two extremes on which Grossman and Lai (2008) focus in their valuable article on parallel trade.

¹⁰The study goes on to document the socioeconomic and demographic characteristics of these inframarginal buyers. Many of these outliers are desperately poor or lacking in insurance. We assume that they would continue buy abroad even if the price differential marginally narrowed.

importers has succeeded.¹¹ It has deterred the 98.5% of US purchasers from reaping the huge savings available had they filled their prescriptions at the same licensed pharmacies that patients in developed countries routinely utilize to treat the same illnesses.

In our model, policies that benefit US consumers do not do so by stimulating more arbitrage. The benefits arise instead because these policies motivate profit-maximizing manufacturers to lower domestic prices to *deter* arbitrage.¹²

It is important to distinguish two kinds of arbitrage that can be triggered if price differences between markets are sufficiently large: (1) personal arbitrage by patients seeking the least expensive cure for their illness and (2) commercial arbitrage by firms that buy and then resell whatever quantity of cures maximizes their profits. While both forms of arbitrage are illegal, personal arbitrage for own use has never been prosecuted. On the other hand, the law against commercial arbitrage is strictly enforced.

That may change. Bills have been proposed to legalize both kinds of arbitrage. In January 2019, the Affordable and Safe Prescription Drug Importation Act (H.R. 447 and S. 97) was introduced in both the House and the Senate. The bill instructs the secretary of health and human services within half a year to issue regulations allowing wholesalers, licensed US pharmacies, and individuals to import qualifying prescription drugs manufactured at FDA-inspected facilities from licensed Canadian sellers and, after two years, grants the secretary authority to permit importation from [other] OECD countries that meet specified or regulatory standards that are comparable to US standards.¹³

Since the threat of personal arbitrage is what currently determines manufacturer pricing, we focus on that form of arbitrage. However, since there is a slim possibility that one of the pending bills will become law, we also discuss the consequences of relaxing the prohibition on commercial arbitrage.

This paper examines the following interventions to lower the prices that US consumers pay: (1) reduc-

¹¹To blur the crucial distinction between safe and counterfeit medications available online, the industry has even succeeded in getting the search engine BING to issue an automated message warning away searchers seeking to consult PharmacyChecker.com, a reputable organization the mission of which is to identify licensed foreign pharmacies from which US patients can fill their prescriptions safely.

¹²The Congressional Budget Office (CBO 2004) concluded that policies to reduce the exogenous threshold, such as legalizing arbitrage or reducing misleading safety warnings, would confer little benefit on US consumers. In reaching this conclusion, CBO disregarded potential reductions in domestic drug prices and confined its estimate of benefits to increases in imports from the European Union and Canada. Under this approach, CBO would have disregarded the policy-induced price changes in our model and, since these are accompanied by no changes in pharmaceutical imports, would have erroneously concluded that no policy change affects consumers.

CBO based its forecast of how changes in pharmaceutical import policies affect consumers in the United States on the experience of consumers in the EU after the introduction of parallel trade in pharmaceuticals. But authorities on parallel trade in the EU explicitly warn against such reasoning, regarding it as based on a false analogy. Although Kyle et al. “found little evidence that parallel trade affected price dispersion of prescription drugs over a 12-year period,” they emphasize that in many countries in their sample, regulations leave pharmacies and patients with no incentive to purchase cheaper offerings of the same product. Hence, manufacturers would have no incentive to reduce the price in the higher-priced market. Kanavos and Costa-Font (2005) explain their statistical findings in the same way. Kyle and colleagues therefore emphasize that their conclusions *should not be applied* to the US market in exercises like the one CBO conducted: “Important differences between the European Union and U.S. markets regarding the regulation of parallel trade and other aspects of pharmaceutical markets make it difficult to predict how parallel trade would fare in the United States. Kyle et al. conclude, “Parallel trade may have less effect in the European Union than it would in higher-price markets like the United States, where pharmacists, insurers, and patients have greater incentive to switch to less expensive prescription drugs” (Kyle et al. 2008).

¹³The threat of imports from all OECD countries is vastly more important since they have a population which is 35 times that of Canada.

ing the concerns of individuals about the safety of importing patented prescription pharmaceuticals from licensed pharmacies in other high income countries; (2) legalizing commercial arbitrage; and (3) allowing Medicare to negotiate or, equivalently, to pay the price negotiated by foreign governments.¹⁴

The first two of these policies are predicted to result in a higher negotiated price abroad. As for the third policy of tying the price Medicare pays to the price foreign negotiated price, it is predicted to lower the foreign price since it would greatly reduce the manufacturer's payoff if bargaining breaks down while leaving the disagreement payoff of the foreign government unchanged.¹⁵

Typically, a policy anticipated to lower prices in the US market will depress innovation and the expected number of future drugs that will be produced. If the policy reduces drug innovation, a second government policy can be used to restore it. Before discussing potential policies, some factual background on drug innovation will be helpful.

Most drug innovation results from research conducted in universities and independent laboratories rather than inside big pharmaceutical companies. According to Shepherd (2018), "Approximately three-fourths of new drugs are externally sourced. Internal R&D is no longer the primary source, or even an important source, of drug innovation in large pharmaceutical companies." The role of the large pharmaceutical companies is to acquire promising molecules that academics have discovered and taken over preliminary FDA hurdles, to surmount the remaining FDA hurdles, and to bring the drugs to market. Manufacturers anticipating lower profit per drug because of government intervention would pay academic researchers less for the promising molecules they discover and, expecting lower reward for their discoveries, those researchers with the lowest probabilities of finding a promising molecule would cease to search for one.¹⁶ As a result, there would be less innovation.

To restore innovation to its previous level, thus offsetting the effect of the price-reducing policy on innovation, a second policy instrument is required.¹⁷ We consider two candidates: (1) the government can replace the money the drug companies cease paying academics who succeed in finding promising molecules, so that the academic who was just indifferent between searching for a molecule and abandoning the search continues to be indifferent, or (2) the government can pay *everyone* who commits to search for a molecule *prior* to the outcome of their research gambles just enough that the marginal academic remains indifferent. Both of these strategies would restore innovation, but one always turns out to be less expensive for the government. It is always cheaper for the government to pay everyone *before* discoveries are made,

¹⁴Two policies have been proposed to link Medicare prices to the prices negotiated by foreign governments. Under international reference pricing, Medicare would pay the average price paid by single-payer OECD countries (Australia, Canada, Finland, New Zealand, Sweden, and the United Kingdom). Under most-favored-nation pricing, Medicare would pay the lowest of the prices paid by these countries for such medications. Since our model abstracts from these differences in foreign prices, the two policies are equivalent.

¹⁵This is not merely the theoretical prediction of my particular bargaining game but of most bargaining games. Moreover, this is not merely a theoretical prediction. Laboratory experiments confirm this prediction (qualitatively, although not quantitatively) both in structured and unstructured bargaining games. See Anbarci and Feltovich (2013) and the references therein.

¹⁶It is important to note, however, that those least likely to succeed are the ones who abandon the search. The lower their success probabilities relative to the academics who continue to search, the less their departure will depress innovation.

¹⁷Price-reducing policies that would depress future innovation would harm future generations of consumers. A model developed by researchers at RAND (Lakdawalla et al. 2009) focuses on this intergenerational trade-off using historical data and a hazard function approach. Their model describes the transition to the long-run, steady-state equilibrium if price-reducing policies are allowed to depress subsequent innovation. In contrast, our model is conceptual. It abstracts from the transitory effects that are the focus of the RAND model and shows how the government can ensure that future innovation does *not* fall when price-reducing policies are imposed. Hence, the two approaches nicely complement each other.

even though vastly more people must be compensated, than to reward only those researchers who succeed in their research gambles. This counterintuitive property is referred to as the “paradox of subsidization.”

We proceed as follows. In Section 2, we introduce our model and use it to analyze the effects of different policies to lower domestic retail prices: promoting importation for personal use, legalizing commercial arbitrage, and tying the price Medicare pays to the foreign negotiated price. In Section 3, we simulate the model to illustrate that when each policy is set to achieve the same reduction in the US retail price, tying to the foreign negotiated price what Medicare pays would cut manufacturer profits much more than promoting arbitrage. In Section 4, we show that this result continues to hold not only in the arbitrage-deterrence model but more generally. Since either policy would reduce manufacturer profits, we then compare two ways of restoring innovation to its previous level. We show that it is cheaper for the government to restore innovation by subsidizing research before its outcome is known than by rewarding only discoveries of potential bio-pharmaceuticals. Section 5 concludes the paper.

2 Personal Arbitrage

Personal arbitrage typically occurs when a patient with a valid US prescription orders online from a foreign pharmacy. Many foreign pharmacies receiving a prescription from an American patient routinely fill the order with the version of that drug approved in their own country. In countries where pharmacists are required to receive a prescription from a *local* doctor, the current practice is for the local doctor to review the US prescription and the patient history and write a new prescription (“cosigning”) for the foreign version of the medication. Although importing prescription drugs into the United States for own use is technically illegal, no one has ever been prosecuted for this “crime,” which is victimless. Some have traveled to a foreign country such as Canada or a member of the EU, filled their prescriptions, and returned home.¹⁸ Enforcement then seems even more problematic since a patient can always disguise the drug purchased abroad by putting it in empty bottles (either from old prescriptions or over-the-counter medications). Even if the authorities were capable of stopping personal arbitrage, it seems unwise politically to separate a grandmother from the only medication she can afford to treat her cancer.

We hypothesize that if patients with valid prescriptions could save enough money by purchasing from foreign pharmacies instead of from American pharmacies, there would be *massive* personal arbitrage. We denote the threshold difference in retail prices as Δ .¹⁹

Let p^U denote the price the manufacturers charge wholesalers in the United States and p^N denote the price they charge wholesalers for the same medication abroad. Let $\tau \geq 1$ denote the exogenous combined markup of wholesalers and retailers at home and abroad, so that the *retail* prices are, respectively, τp^U and τp^N . We assume that massive personal arbitrage will occur if $\tau(p^U - p^N) > \Delta$ and none (apart from inframarginal imports) will occur if $\tau(p^U - p^N) \leq \Delta$. The US government can lower Δ exogenously by scaling down misleading FDA warnings about the riskiness of taking medications routinely dispensed by licensed pharmacies in other high income countries; legalizing personal arbitrage would have similar effects, since it would reassure US consumers about the safety of prescriptions filled at such pharmacies.

¹⁸In a signed letter to the *New York Times*, a rheumatologist observed that “a patient could fly first class to Paris, stay at the Ritz, dine at a top Michelin restaurant, buy a one-year supply of Humira [a rheumatoid arthritis drug] at local prices in France, fly back home and finish with enough profit to hire a registered nurse to administer the injection every two weeks” (Hanauer 2019).

¹⁹We assume that there is a negligible set of desperate outliers with much smaller thresholds.

We consider $n \geq 1$ manufacturers producing patented perfect substitutes (such as the four DAAs to cure hepatitis C) at zero marginal cost and selling them at a market-determined price in the United States and at a negotiated price ceiling in the EU and Canada. These assumptions are similar to those in the arbitrage-deterrence model sketched briefly by Ganslandt and Maskus (2004) as background for their main model. There are two key differences: (1) the price cap in their model is exogenous rather than negotiated, and (2) they limit attention to a monopolist manufacturer ($n = 1$) rather than accounting for oligopolists.²⁰ The cap is set in the following game between the n manufacturers and the negotiator.

2.1 Description of the Bargaining Game of Perfect Information

We envision the following game. A single negotiator specifies a discounted price p^N per cure at which to purchase medication for each of the (exogenous) Q^N sufferers of a specific malady (such as hepatitis C).²¹ The negotiator proposes this price sequentially to each of the n drug manufacturers. If l accept his proposal, he orders Q^N/l from each of them. Those rejecting the negotiator's proposal produce and sell only in the unregulated (US) market. Those accepting it sell not only in the US market but also in the foreign market. In the next subsection, we deduce the unique subgame-perfect equilibrium of this bargaining game; we also show in footnote 26 that the same equilibrium arises if the manufacturers respond to the negotiator's proposal simultaneously instead of sequentially.

Intuitively, manufacturers benefit if they accept the negotiator's proposal since each manufacturer can then sell in the foreign market a drug that is costless to produce. On the other hand, every manufacturer also incurs a cost in the US market if any of them accepts the negotiator's proposal because of actual or potential arbitrage. If Q^N were small relative to the size of the US market, importation would be insignificant and the manufacturers would accommodate arbitrage by playing Cournot using a demand curve shifted inward slightly by the negligible amount Q^N . That is, manufacturers would sell in the US market to the vast majority of patients lacking the good fortune to have acquired the Q^N imports. However, since pharmaceuticals would be imported not only from Canada but from all the other OECD countries, Q^N is large relative to the US market and manufacturers would find arbitrage deterrence more profitable than accommodation.²² Hence, the consequence of any manufacturer accepting the negotiator's proposal is a retail price in the US market of at most Δ more than the retail price abroad.

Given the extremely low marginal costs of production for most drugs (recall the costs reported in Section 1), we assume that producing additional units is costless.²³ In addition, we assume that the drugs in this therapeutic class are perfect substitutes and therefore sell at the same price. Throughout, we assume that domestic retail demand, denoted $D(\cdot)$, depends on the retail price $p = \tau p^U$ and satisfies the following conditions: (1) $D(0)$ is finite, (2) $pD(p)$ is strictly concave and achieves a maximum at $p^* > \Delta > 0$, and (3)

²⁰They also omit the "unconnected case" where, even if the domestic price were set at the monopoly level in their model, no arbitrage would occur because the combined cost of acquiring and transporting drugs is too high to make arbitrage profitable. Ganslandt and Maskus do not conduct comparative statics in their preliminary model. But since our goal is to assess the effects of alternative policies on the equilibrium, endogenizing the negotiated price cap is crucial. We allow there to be more than one manufacturer so that our model can be applied to markets where several manufacturers offer patented drugs that are therapeutically equivalent (like the market for DAAs to cure hepatitis C).

²¹Given the observations of Kyle et al. (2008) and others that most patients in the EU are insulated from price changes, we assume that Q^N is completely insensitive to price.

²²For a more formal statement, see footnote 24.

²³Ganslandt and Maskus make the same assumption.

there is a unique Cournot equilibrium in the game where the n manufacturers sell simultaneously in the US market and earn $p/\tau = p^U$ per cure.

The negotiator approaches each manufacturer in sequence and proposes to pay p^N per cure for $\frac{Q^N}{l}$ cures, where $l = 1, \dots, n$ is the number of manufacturers that accept. After the last manufacturer makes his decision, payoffs in the bargaining game are collected. The payoffs result from the subsequent simultaneous sales by the n manufacturers.

If every manufacturer rejects the negotiator's proposal, then each of the n manufacturers sells only in the US market and receives an equal share of Cournot retail profits deflated by the markup factor (τ). If $l \geq 1$ manufacturers accept the negotiator's proposal but $\tau p^N + \Delta > p^{Cournot}$, then those accepting the proposal earn $p^N Q^N / l$ in the foreign market while those rejecting it earn nothing there. The US retail price is $p^{Cournot}$, which is insufficient to compensate arbitrageurs given the high cost of acquiring foreign drugs. No arbitrage occurs. Every manufacturer therefore again earns in the US market an equal share of Cournot profits deflated by the markup factor (τ).

If $\tau p^N + \Delta < p^{Cournot}$ and at least one of manufacturers accepts the negotiator's proposal ($l \geq 1$), then each of the l manufacturers earns $p^N Q^N / l$ in the foreign market while the $n - l$ others earn nothing in that market. In the US market, however, a price of $p^{Cournot}$ would attract massive arbitrage. To deter it, *limit pricing* occurs instead. Each manufacturer sells enough more than its Cournot output that the retail price drops to $\tau p^N + \Delta$. No manufacturer would unilaterally sell less than $D(\tau p^N + \Delta) / n$, under a weak condition insuring that arbitrage deterrence occurs in equilibrium.²⁴ Nor would any manufacturer unilaterally sell more than this quantity since, with every firm producing an output exceeding the Cournot level, selling more would drive the US retail price further away from the revenue-maximizing level. Hence, if any manufacturer accepts the proposal, the retail price in the US market would be $\tau p^N + \Delta$, but no importing would occur.

In Table 1, we list for any proposed p^N the payoffs manufacturer i would receive in this bargaining game. These payoffs depend not only on his accept-reject decision but on those of the $n - 1$ other manufacturers.

2.2 The Unique Subgame-Perfect Equilibrium in the Bargaining Game

We now consider how each manufacturer in the sequence would respond to any proposed p^N . Each manufacturer in the sequence would find himself in one of two situations: either (1) some firm earlier in the sequence had already accepted the negotiator's proposed price p^N or (2) no previous manufacturer had accepted the proposed price. We work backwards, considering first the optimal choice of the final manufacturer in the sequence.

²⁴As long as the arbitrage would be sufficiently massive, every manufacturer has an incentive to deter it. In particular, no manufacturer would unilaterally deviate from arbitrage deterrence as long as $p^U \left(D(\tau p^U) - \frac{n-1}{n} D(\tau p^N + \Delta) - Q^N \right) \leq \frac{(\tau p^N + \Delta) D(\tau p^N + \Delta)}{\tau n}$ for all $p^U > p^N + \Delta / \tau$. The right-hand side is the payoff each manufacturer gets in the US market if arbitrage is deterred. The left-hand side is the payoff from a unilateral contraction by one firm in its domestic sales: the deviation would raise the domestic retail price to some $\tau p^U > \tau p^N + \Delta$ and therefore would reduce domestic demand to $D(\tau p^U)$. Part of that domestic demand (Q^N) would be satisfied by imports; part of it would be satisfied by the $n - 1$ non-deviating firms, each of which is still conjectured, as before (under the Cournot conjecture), to sell $D(\tau p^N + \Delta)$ in the domestic market. The remaining demand is satisfied by the deviating firm. The inequality says that no firm has a profitable unilateral deviation from arbitrage deterrence. This inequality is clearly satisfied if $Q^N \geq D(\tau p^N + \Delta) / n$ since the left-hand side would then be negative. But Q^N need not be so massive to satisfy it.

Table 1: Payoffs to Manufacturer i

Manufacturer i is among / who accept	$\frac{p^N Q^N}{l} + \frac{1}{\tau n} \min(\pi^{Cournot}, (\tau p^N + \Delta)D(\tau p^N + \Delta))$
Manufacturer i rejects but others accept	$0 + \frac{1}{\tau n} \min(\pi^{Cournot}, (\tau p^N + \Delta)D(\tau p^N + \Delta))$
Manufacturer i rejects as does everyone else	$\frac{\pi^{Cournot}}{\tau n}$

We consider two cases. In the first case, the proposed price satisfies:

$$p^N Q^N + \frac{(\tau p^N + \Delta)D(\tau p^N + \Delta)}{\tau n} > \frac{\pi^{Cournot}}{\tau n}. \quad (2.1)$$

If someone previously had accepted the proposal, the final manufacturer would accept as well. For, even if he rejected the proposal, there would still be Q^N cures that would flood the US market unless arbitrage was deterred. By accepting and selling in the foreign market, he would earn revenue additional to his domestic sales.

If no one had previously accepted, the final manufacturer would strictly prefer to accept. For by being the only manufacturer to accept, he would earn $p^N Q^N$ in the foreign market plus $\frac{(\tau p^N + \Delta)D(\tau p^N + \Delta)}{\tau n}$ in the domestic market, which according to inequality (2.1) strictly exceeds $\pi^{Cournot} / \tau n$, the revenue he would earn if he rejected the negotiator's proposal. So the final manufacturer would accept such a proposal even if no firm prior to him had accepted it.

Turning now to the optimal decision of the penultimate manufacturer, he would accept the proposal if any previous manufacturer had accepted; for, there would then be the arbitrage threat of the Q^N cures in the foreign market whether he accepted or rejected the proposal, and he would strictly increase his revenue by also selling in the foreign market. If no previous manufacturer had accepted the proposal, the penultimate manufacturer would anticipate that if he rejected it as well, the final manufacturer would nonetheless accept it since that is his best reply in that situation. Thus, the penultimate manufacturer recognizes that there would be Q^N cures in the foreign market to be deterred from flooding the US market regardless of his decision; he accepts and strictly increases his revenue by $p^N Q^N / 2$ since he would divide the foreign market with the final manufacturer.

Any previous manufacturer would behave in the same way. If someone had previously accepted, he would accept to get some share of the foreign market. If no one had previously accepted and he also rejected, he would anticipate that every subsequent manufacturer would best-reply by accepting the negotiator's proposal. Hence, he would anticipate that regardless of what he did the Q^N cures would still loom over the US market and that by accepting he would get an additional $p^N Q^N / (1 + z)$ in revenue, where z is the number of manufacturers who move after him.

Suppose instead the proposed p^N satisfies the following inequality:

$$p^N Q^N + \frac{(\tau p^N + \Delta)D(\tau p^N + \Delta)}{\tau n} < \frac{\pi^{Cournot}}{\tau n}. \quad (2.2)$$

As before, the final manufacturer and every predecessor would accept the proposed price if any previous manufacturer had previously accepted it. Suppose, however, that the final manufacturer observed that no one had previously accepted the proposed price. If he accepted it, inequality (2.2) indicates that he would be strictly worse off than if he joined his predecessors in rejecting the proposal and competed only in the US market; for if none of the n manufacturers sells in the foreign market, there would be no need to deter arbitrage and he would earn his share of Cournot profits deflated by the markup τ . Now consider the penultimate manufacturer. If he observed that no one had previously accepted the negotiator's proposal, then—anticipating that the final manufacturer would reject it if he did, he would reject p^N as being too low. Indeed, *every* prior manufacturer would be in the same position. If he rejected the proposal, every subsequent manufacturer would do so as well and there would be no threat of imports flooding the US market. The n firms would each get a share of the Cournot profits in the US market.

Denote as \mathbf{p}^N the smaller solution to the following equation, assuming it is nonnegative.²⁵

$$p^N Q^N + \frac{(\tau p^N + \Delta)D(\tau p^N + \Delta)}{\tau n} = \frac{\pi^{Cournot}(n)}{\tau n}. \quad (2.3)$$

Since the foreign negotiator wants to purchase Q^N cures at the lowest price, he would propose a price just above \mathbf{p}^N .²⁶ In the play of the game, every manufacturer accepts proposal \mathbf{p}^N , and each firm receives $1/n^{\text{th}}$ of the additional Q^N sales. The retail price in the US market falls to $p = \tau p^N + \Delta$, just low enough that to deter arbitrage. The n manufacturers sell Q^N cures in the negotiated market and $D(\tau p^N + \Delta)$ in the unnegotiated market.

Denote the revenue received by each of the n manufacturers as $R(n)$. Each manufacturer earns revenue

$$R(n) = \frac{\mathbf{p}^N Q^N}{n} + \frac{(\tau \mathbf{p}^N + \Delta)D(\tau \mathbf{p}^N + \Delta)}{\tau n}. \quad (2.4)$$

$$= \frac{\pi^{Cournot}(n)}{\tau n} - \frac{n-1}{n} \mathbf{p}^N Q^N, \quad (2.5)$$

where the last line is obtained by substituting into (2.4) the solution to (2.3). Equation (2.5) implies that in equilibrium each firm earns smaller profits when the n firms sell in both markets than it would if the n firms sold only in the domestic market. This counterintuitive property is common in games.²⁷

²⁵The smaller solution will be negative if $\Delta > p^{Cournot}$. In this “corner” case, $\mathbf{p}^N = 0$, and the US retail price will be $p^{Cournot}$. Since the price differential between the two regions is strictly smaller than Δ , no one will be tempted to import. Each manufacturer in this case earns $R(n)/n = \pi^{Cournot}(n)/\tau n$.

²⁶If the n manufacturers respond simultaneously instead of sequentially to the negotiator's proposal, there are two equilibria. There is a degenerate equilibrium where everyone accepts a proposed p^N no matter how low it is. Rejecting the proposal unilaterally does not alter the need for arbitrage deterrence and merely reduces a manufacturer's own revenue by $p^N Q^N/n$. This equilibrium has no counterpart in the subgame-perfect equilibrium of the sequential game. The second equilibrium in the simultaneous-move game is the counterpart of the subgame-perfect equilibrium in the sequential game. It is an equilibrium in the simultaneous-move game for everyone to reject the proposed price \mathbf{p}^N defined implicitly by inequality (2.2). For, each manufacturer would receive the payoff on the right-hand side of this inequality whereas if one player unilaterally deviated by accepting the proposal, he would receive the profit on the left-hand side. If p^N is reduced, the left-hand side is even smaller while the right-hand side does not change. Hence, rejecting the proposal remains an equilibrium for any proposed price lower than \mathbf{p}^N . If the proposed price instead satisfies inequality (2.1), however, this unilateral deviation is strictly profitable and rejection is no longer an equilibrium. What is the equilibrium in this case? Any proposed price higher than \mathbf{p}^N will be accepted by the n manufacturers; for, if any manufacturer unilaterally rejected the proposal, he would lose $p^N Q^N/n$ revenue from the foreign market. Hence, to obtain Q^N cures at the lowest price, the negotiator would propose a price marginally above \mathbf{p}^N and every manufacturer would accept the proposal. None of the Q^N sold in the foreign market would be imported back to the US.

²⁷For example, in the prisoner's dilemma full cooperation is preferred by each player to the equilibrium outcome, and in a symmetric Cournot game, an equal share of the monopoly profit is preferred by each firm to the oligopoly equilibrium.

It is helpful to rearrange equation (2.3) as follows:

$$(\tau p^N + \Delta)D(\tau p^N + \Delta) = \pi^{Cournot}(n) - \tau n p^N Q^N. \quad (2.6)$$

The right-hand side is a decreasing linear function of p^N with vertical intercept $\pi^{Cournot}(n)$ and slope $-\tau n Q^N < 0$. The left-hand side is a strictly concave function with vertical intercept $\Delta D(\Delta) \geq 0$. Given our assumptions about the function $D(\cdot)$, domestic total retail revenue $(\tau p^N + \Delta)D(\tau p^N + \Delta)$ is strictly increasing at $p^N = 0$.

Since Cournot profit is strictly smaller than monopoly profit (for $n = 2, \dots$), the vertical intercept of the line is strictly smaller than the peak of the concave profit function. There are two possible cases. In the first case, $\Delta \leq p^{Cournot}$, the domestic and foreign markets are “connected” and $\mathbf{p}^U = \mathbf{p}^N + \Delta/\tau$; in the second case, $\Delta > p^{Cournot}$, the two markets are “unconnected” and $p^N = 0$ while $\mathbf{p}^U = p^{Cournot}/\tau$. The first case (respectively, the second case) arises if the vertical intercept of the single-peaked function lies below (resp. above) the vertical intercept of the downward-sloping line. In the two cases,

$$\mathbf{p}^U = \min \left(\mathbf{p}^N + \Delta/\tau, p^{Cournot} / \tau \right).$$

In the connected case, the horizontal component of the point of intersection is the manufacturer’s foreign price (\mathbf{p}^N), and the vertical component is the total retail revenue in the domestic market. In the unconnected case, the negotiated manufacturer’s price abroad equals the marginal production cost (assumed, for simplicity, to be zero), and the retail price in the US market is the Cournot price.

We depict the determination of \mathbf{p}^N in Figure (2.1):

2.3 Comparative Statics

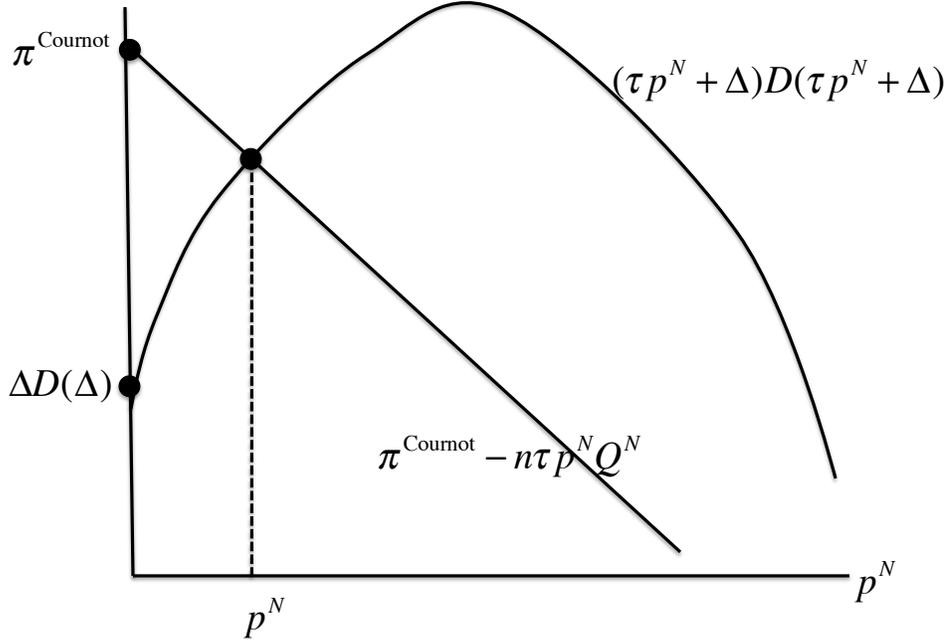
We now consider three government policies that would reduce the domestic price of prescription drugs: (1) ceasing to discourage imports from online pharmacies licensed in high income countries and certified safe by the government (e.g. FDA) or the private sector (e.g. PharmacyChecker.com)— $\Delta \downarrow$; (2) increasing competition among manufacturers— $n \uparrow$; and (3) tying the price Medicare pays to the price negotiated by foreign governments— $Q^N \uparrow, D(p) \downarrow$. We also show how these policies would affect the negotiated price p^N and the profit of each manufacturer. Under each of these policies, manufacturer profit falls when the domestic retail price falls. As a result, innovation would fall unless a second policy instrument is used to offset the effect. We compare two candidates for this second instrument in Section 4.

In analyzing the effects of a change in each exogenous parameter, we consider first the case where the two markets are connected and then the case where they are unconnected. Results for both cases are summarized in the three rows of Table 2; the parentheses in each cell contain the result for the unconnected case, with “NC” denoting “no change.”

2.3.1 Reducing Δ

If the FDA reassured US patients that they could safely import drugs ordered online from pharmacies licensed in high income countries and certified as safe, Δ would be reduced. An exogenous reduction in Δ will raise the foreign negotiated price. For if that negotiated price did not increase, manufacturers would earn strictly more by selling exclusively in the domestic market and would reject the negotiator’s proposed

Figure 2.1: Response to the Threat of Commercial Arbitrage and Personal Arbitrage



price (see equation (2.11)). To acquire any drugs, therefore, the negotiator would have to propose a higher price (p^N). Since an exogenous reduction in Δ leads to an increase in p^N , what can be said about $\tau p^N + \Delta$, the domestic retail price? This sum must fall. Otherwise, the left-hand side of (2.11) would strictly exceed the right-hand side, and the negotiator could secure a lower price. Since the domestic retail price falls, so must the price (p^U) that manufacturers charge domestic wholesalers. Since p^N will rise, equation (2.5) implies that the reduction in Δ must cause \mathbf{R} to fall. Each manufacturer loses more revenue in the domestic market than it gains in the foreign market.

In terms of Figure (2.1), an exogenous decrease in Δ will shift the single-peaked function down in the neighborhood of the equilibrium. To see this, note that at a fixed Δ , $(p^N + \Delta)D(p^N + \Delta)$ is strictly increasing in p^N where it intersects the downward-sloping line, and hence at a fixed p^N , this function must be strictly increasing in Δ . But if Δ decreases, it will shift the curve downward to the left of its peak (and upward to the right of its peak), and consequently the intersection with the unchanged downward-sloping line will occur at a higher p^N .

If Δ is initially so large that the two markets are unconnected ($\Delta > p^{\text{Cournot}}$), then producers sell to foreign wholesalers at $p^N = 0$ (marginal cost) and to domestic wholesalers at $p^U = p^{\text{Cournot}}/\tau$. Since $\tau(p^U - p^N) < \Delta$, there is no incentive for personal arbitrage, and a reduction in Δ within the unconnected region will affect neither the two prices nor any manufacturer's profit.

As Δ is lowered within the connected region from p^{Cournot} to zero, the higher domestic retail price falls

Table 2: Comparative Statics

	p^N	p^U	R
Q^N	- (NC)	- (-)	- (-)
n	- (NC)	- (-)	- (-)
Δ	- (NC)	+ (NC)	+ (NC)

and lower foreign retail price rises. At $\Delta = 0$ the two converge at a price below $p^{Cournot}$. Throughout this region the difference in the two prices is just sufficient to deter importation from the foreign market.²⁸

2.3.2 Increasing the Number of Manufacturers

An exogenous increase in the number (n) of manufacturers will cause the negotiated price (p^N) to fall. For if the negotiated price did not decrease, the manufacturers would strictly prefer to sell in both markets rather than exclusively in the US market (see equation (2.11)), and the negotiator would secure a lower price. For the difference in manufacturers' prices to remain unchanged (Δ/τ), the domestic price (p^U) must fall by the same amount as the negotiated price. Each manufacturer's profit would also fall, since total revenue in each market falls (equation 2.4) and must be divided among a larger number of manufacturers.

Graphically, an increase in n does not affect the domestic industry revenue curve in Figure (2.1) but shifts the intercept of the line down since, in a symmetric Cournot equilibrium, industry profits decline as the number of competitors increases. The increase in the number of manufacturers also causes the line to steepen. As a result, the intersection point has a smaller horizontal and a smaller vertical component. The horizontal component is the negotiated price. Since it falls, manufacturers collectively earn less in the foreign market. The vertical component is the aggregate revenue collected from domestic consumers. Since it falls, manufacturers collectively earn less in the domestic market. Since these reduced aggregate revenues are divided among more firms, the revenue per firm R also falls.

If Δ is so large that the two markets are unconnected ($\Delta > p^{Cournot}$), an exogenous increase in the number of manufacturers will leave the negotiated price at the marginal cost of production and will reduce the domestic price because there would be more Cournot competitors. In the foreign market, profits would continue to be zero, while in the domestic market, the reduced industry revenue divided among a larger number of manufacturers would result in lower revenue per manufacturer (R).

²⁸It should be noted that a similar result occurs if a monopolist engages in third-degree price discrimination where the price difference is constrained by the threat of arbitrage; tightening the constraint causes the monopolist to raise the lower price and lower the higher price. But the mechanism is entirely different. There is only one producer in the case of third-degree price discrimination and no bargaining; moreover, the market with more elastic demand (our domestic market) has the lower price.

2.3.3 Tying the Medicare Price to the Negotiated Foreign Price

If bargaining breaks down, the negotiator purchases from some other firm(s) the next best alternative, another drug that is cheaper although inferior; as for the n manufacturers, if bargaining breaks down they no longer need to deter arbitrage and can sell at the Cournot price in the domestic market.

Suppose instead that Medicare commits to paying the negotiated foreign price, p^N . If bargaining breaks down, the negotiator's next best alternative is unchanged. But the manufacturers lose massive sales to Medicare, which also buys from some other manufacturer(s) an inferior but less expensive alternative. In most bargaining games, a bargainer gains power if his disagreement payoff does not change while his adversary's disagreement payoff falls. This is not merely a theoretical prediction but one that has been observed in both the field and the laboratory. In the field, it is the basis for what *Wikipedia* refers to as "collective buying power: the ability of a group of consumers to leverage the group size in exchange for discounts." Anbarci and Feltovich (2013) review standard bargaining games and find that all of them reach the same conclusion: the more one side has to lose if bargaining breaks down, the weaker its position—provided the other side's disagreement payoff is unchanged. They then verify qualitatively that this predicted behavior occurs in the laboratory.

In our bargaining game, if Medicare commits to paying the negotiated foreign price (p^N), the disagreement payoff of the negotiator does not change, but the situation of the n manufacturers does change. If bargaining breaks down, the disagreement payoff of each manufacturer falls: that is, the Cournot profit they divide equally falls because it no longer includes Medicare demand.²⁹

However, the situation is more complicated since the payoff the n firms receive if they *accept* an unchanged price p^N would also change; they would receive less revenue from non-Medicare sales in the US but more revenue from selling to Medicare at p^N .

As long as the disagreement payoff of each manufacturer falls more than the revenue they would receive if each of them accepted the negotiator's unchanged p^N , the negotiator will propose a strictly lower p^N . We now verify formally that p^N strictly decreases.

In equation (2.3), multiply by τn and subtract $\pi^{Cournot}$ from both sides of the equation. To capture the effects of the policy, insert a shift parameter α in the domestic demand curve $D(p; \alpha)$ and sales at the foreign price $Q^N(\alpha)$. Assume that when α increases exogenously, the demand curve strictly increases ($D_2(p; \alpha) > 0$) and sales at the negotiated price strictly decrease ($Q^{N'}(\alpha) < 0$). An exogenous *reduction* in α reflects Medicare shifting marginally from paying the US price to paying the negotiated price. Decompose $\pi^{Cournot}$ into its two factors: the Cournot price $p^{Cournot}(\alpha)$ and the domestic demand at the Cournot price

²⁹In our formal model, we assume that there is a single foreign country with a single negotiator as would be appropriate if an EU negotiator bargained to get the lowest price for all EU members. In reality, however, each EU country negotiates the price of a given medication with its manufacturer and often countries secure different prices for the same medication. If Medicare committed to paying the average of these prices, it would empower each negotiator to secure lower prices than could be achieved without this linkage. For, given the linkage, the country paying the highest of those prices could tell the manufacturer: "Charge us what the average price will fall to if we were to abandon you and buy a near substitute from another manufacturer. After all, Medicare would pay you that same average price whether you accept our demand or not; but keeping us as customers gives you larger volume and profit." After the manufacturer agreed to the price reduction, another country would have the highest price and could use the identical argument to secure a price concession. . . Since the process would continue until the highest of the re-negotiated prices equals the lowest price, the end result would be that every country in the price index bargains its price down to the lowest price and that is what Medicare pays as well. This result holds regardless of the number of countries indexed and whether the average price to which Medicare is linked is weighted by population or not.

$D(p^{Cournot}(\alpha); \alpha)$.

Then we obtain:

$$l(p^N; \alpha) = p^{Cournot}(\alpha)D(p^{Cournot}(\alpha); \alpha) - n\tau p^N Q^N(\alpha) - (\tau p^N + \Delta)D(\tau p^N + \Delta; \alpha) = 0. \quad (2.7)$$

Denote partial derivatives of $l(p^N; \alpha)$ by subscripts. Then, $\frac{dp^N}{d\alpha} = -\frac{l_2(p^N; \alpha)}{l_1(p^N; \alpha)}$. Notice that $l_1 < 0$ since the first term in (2.7) is constant and the two terms subtracted off strictly increase in p^N .

To show that p^N will fall when the policy is introduced, we wish to show that an increase in α in the neighborhood of the equilibrium causes $l(p^N; \alpha)$ to increase at every p^N . That is, we wish to confirm that, under reasonable assumptions, $l_2(p^N; \alpha) > 0$. Assume that (1) $D_{12}(p; \alpha) \geq 0$ and (2) $D_{11} \leq 0$. These assumptions are sufficient (but by no means necessary) to show that the Cournot price and profit are increasing in α .³⁰

Differentiating partially, we obtain:

$$l_2(p^N; \alpha) = p'^{Cournot}(\alpha) \left(D(p^{Cournot}(\alpha); \alpha) + p^{Cournot}(\alpha)D_1(p^{Cournot}(\alpha); \alpha) \right) \quad (2.8)$$

$$+ D_2(p^{Cournot}(\alpha); \alpha) \left(p^{Cournot}(\alpha) - (\tau p^N + \Delta) \frac{D_2(\tau p^N + \Delta; \alpha)}{D_2(p^{Cournot}(\alpha); \alpha)} \right) \quad (2.9)$$

$$- n\tau p^N Q'^N(\alpha) > 0. \quad (2.10)$$

The partial derivative is strictly positive because each of its three terms are positive. The first term (2.8) is the product of two factors. The Cournot price is increasing in α as established in footnote 30. The second factor is positive, since the Cournot price is smaller than the revenue-maximizing monopoly price. The second term (2.9) is again the product of two factors. The first is strictly positive because we defined α as a parameter that shifts the demand curve rightward. The second factor is strictly positive because it is the difference between the Cournot price and the smaller US retail price multiplied by a fraction no larger than 1 (since $D_{12} \geq 0$). The third term (2.10) is positive since $Q'^N(\alpha) < 0$.

It follows that, in the connected region, p^N is increasing in α . Hence, when the policy is implemented and α decreases exogenously, p^N decreases. Since p^U and p^N differ by a constant, p^U must decrease at the same rate.

In the connected region, the decrease in α lowers revenue from sales in the United States. Although the foreign manufacturers' price (p^N) falls, volume (Q^N) rises due to increased Medicare demand so revenue from sales at the negotiated price may rise or fall. If $p^N Q^N$ falls, then manufacturer revenue falls in each market and hence overall revenue falls. If revenue in the foreign market rises, then the first term in equation (2.5) falls and the second one rises, establishing that overall manufacturer revenue falls. In this latter case, the decrease in revenue in the US market more than offsets the increase in revenue in the foreign market, so overall revenue falls.

If the two markets are unconnected, an exogenous increase in the number paying the negotiated price and an equal decrease in the number paying the market-determined price will leave the negotiated price

³⁰Define the Cournot first-order condition as $f(p^{Cournot}; \alpha) = p^{Cournot} + \frac{D(p^{Cournot}; \alpha)}{nD_1(p^{Cournot}; \alpha)} = 0$. Then, $\frac{dp^{Cournot}}{d\alpha} = -\frac{f_2(p^{Cournot}; \alpha)}{f_1(p^{Cournot}; \alpha)}$. Differentiating partially and using our assumptions on $D(p; \alpha)$, it is straightforward to show that $f_1(p^{Cournot}; \alpha) > 0$ and $f_2(p^{Cournot}; \alpha) < 0$. Hence, $p'^{Cournot}(\alpha) > 0$. Moreover, Cournot profit is also strictly increasing in α . Differentiating $\pi(\alpha) = p^{Cournot}(\alpha)D(p^{Cournot}(\alpha); \alpha)$, we conclude that $\frac{d\pi(p; \alpha)}{d\alpha} > 0$. Intuitively, an increase in α with the price fixed raises profit because the quantity demanded increases. An increase in price with α fixed will then increase profit since the Cournot price is below the revenue-maximizing monopoly price.

unchanged (at the marginal cost, assumed to be zero) and will depress the market-determined price (since the Cournot price falls when the demand curve shifts inward). The revenue of each manufacturer will decline: foreigners who previously paid the negotiated price continue to pay zero; those who pay the domestic retail price, which has declined, pay less; and the people who switch from paying a positive amount to paying zero also pay less. Hence, revenue per firm (\mathbf{R}) declines.

We summarize these comparative-statics results in Table 2.

2.4 Commercial Arbitrage

We have postponed discussion of commercial arbitrage until now because (1) the ban on it is currently strictly enforced and (2) even if in the future the ban is lifted or the penalties for engaging in it significantly reduced, the analysis parallels that of personal arbitrage.

Commercial arbitrage involves the purchase of drugs from foreign wholesalers and the re-sale to US wholesalers by profit-seeking arbitrageurs. To acquire the drug, an arbitrageur must pay the foreign wholesaler at least as much as a foreign pharmacy would pay that wholesaler; and to sell it, the arbitrageur cannot hope to receive more than a US wholesaler would pay the manufacturer to obtain the same drug. Hence, the profit per cure an arbitrageur can expect is $p^U - \tau_w p^N$, where $\tau_w \in (1, \tau)$ denotes the foreign wholesale markup over the manufacturers' price. If this price differential exceeds an exogenous threshold, Δ^c dollars per cure, I assume that massive commercial arbitrage would occur. None occurs if and only if:

$$p^U - \tau_w p^N \leq \Delta^c. \quad (2.11)$$

Figure 2.2 depicts both the personal arbitrage constraint and the commercial arbitrage constraint and clarifies the relationship between them. The foreign manufacturers' price is on the horizontal axis and the US manufacturers' price is on the vertical axis. The personal arbitrage constraint is depicted as a line sloping upward at 45 degrees with a vertical intercept of Δ/τ ; the commercial arbitrage constraint is depicted as a line sloping upward at a steeper slope with vertical intercept Δ^c . No arbitrage occurs if the two manufacturers' prices (p^N, p^U) lie on or below both arbitrage constraints. In addition, the manufacturers' price in the US cannot exceed $p^{Cournot}$. Hence, p^U must lie on or below the lower envelope $p^U = \min(p^{Cournot}; p^N + \Delta/\tau; \tau_w p^N + \Delta^c)$.

Figure 2.2 depicts the determination of the negotiated price from a different perspective than Figure 2.1. In Figure 2.2, the proposed foreign price p^N that would just be acceptable to manufacturers if they charged domestic wholesalers p^U lies on the locus defined by the following equation:

$$np^N Q^N + \frac{\tau p^U D(\tau p^U)}{\tau} = \frac{\pi^{Cournot}}{\tau} \quad (2.12)$$

Since the first term on the left-hand side is increasing in p^N and the second term on that side is increasing in p^U (for τp^U below the monopoly price), the locus is downward-sloping.

Any foreign price proposed by the negotiator strictly to the left of this locus would be rejected; any proposed price on it or to its right would be accepted. If the markets are connected, the equilibrium negotiated price is the *smallest* p^N that (1) deters massive arbitrage but (2) is acceptable to the manufacturers. This occurs where the downward-sloping line intersects the upward-sloping lower envelope of the two arbitrage constraints.

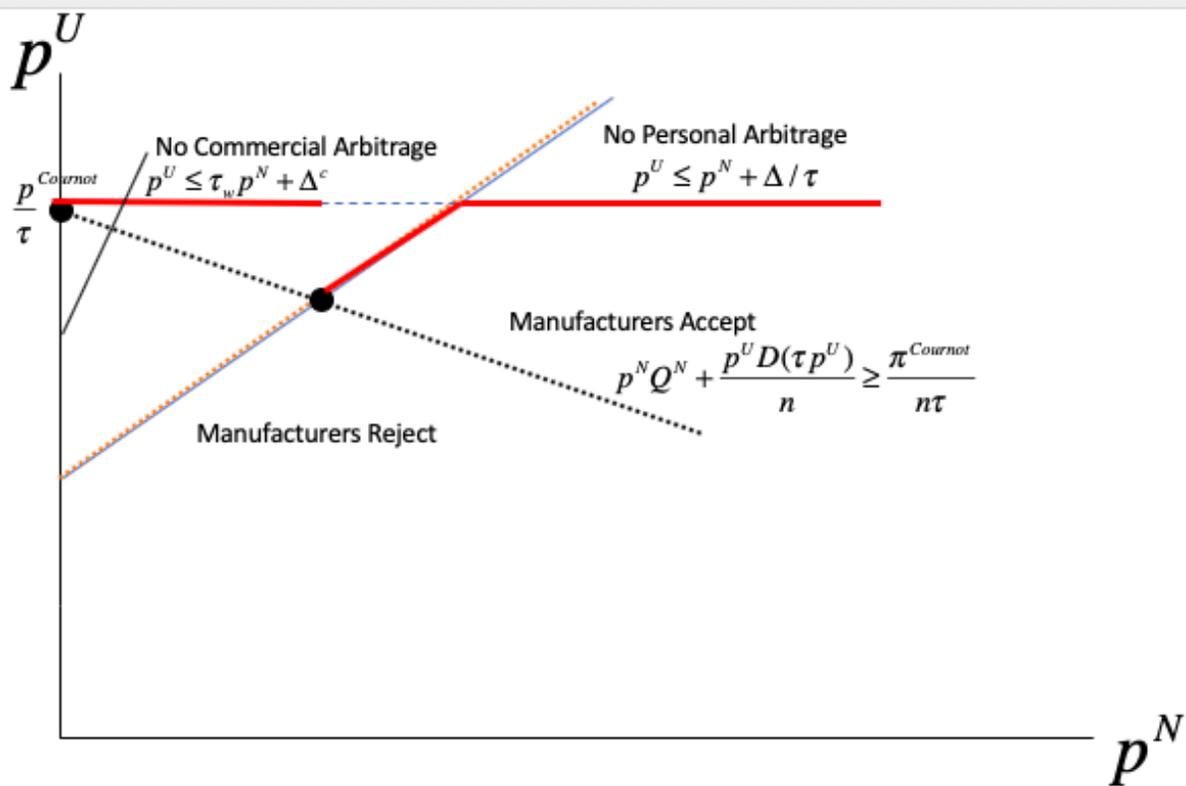


Figure 2.2: Determination of the Negotiated Price

Policies that shift the downward-sloping locus against an unchanged upward-sloping locus will result in the US price and negotiated foreign price changing in the *same* direction. If n or Q^N increased exogenously, a point (p^N, p^U) on the locus (2.12) would instead fall in the interior of the acceptance region since such changes would result in the left-hand side exceeding the right-hand side. This implies that such changes would shift the locus leftward and would lower both the US and the foreign manufacturers' prices. This is consistent with what we reported in the first two rows of Table 2. If Δ^c was sufficiently low that commercial arbitrage constraint replaced the personal arbitrage constraint as the one that is binding, the qualitative effect of increasing Q^N or n would also be to lower both prices.

Policies that shift the upward-sloping locus against an unchanged downward-sloping locus will result in the US price and the negotiated foreign price changing in opposite directions. Thus, we saw in the third row of Table 2 that an increase in Δ would lower the foreign manufacturers' price but would raise the US domestic price when the personal arbitrage constraint is binding and the commercial arbitrage constraint is slack. If Δ^c was sufficiently low that commercial arbitrage was binding and the personal arbitrage constraint was slack, the qualitative effect of increasing Δ^c would likewise be to lower the foreign manufacturers' price and to raise the US manufacturers' price.

Finally, if the penalties for commercial arbitrage are relaxed enough that the the commercial arbitrage constraint replaces the personal arbitrage constraint as binding, then, as Figure 2.2 reflects, the negotiated manufacturers' price will rise and the US domestic price will fall.

The effects of changes in exogenous parameters on the manufacturers' prices have been deduced under the assumption that the commercial arbitrage constraint is binding. It is equally straightforward to deduce the effects of these changes on revenue per firm, which we denote \mathbf{R}^c . Denote the equilibrium negotiated price when the commercial arbitrage constraint binds as $\mathbf{p}^{N,c}$. It is defined implicitly as the smaller solution to:

$$p^N Q^N + \frac{1}{\tau n} \tau (t_w p^N + \Delta^c) D \left(\tau (t_w p^N + \Delta^c) \right) = \frac{\pi^{Cournot}}{\tau n}. \quad (2.13)$$

The combined revenue from the two markets would be:

$$\mathbf{R}^c = \frac{\mathbf{p}^{N,c} Q^N}{n} + \frac{1}{\tau n} \tau (t_w \mathbf{p}^{N,c} + \Delta^c) D \left(\tau (t_w \mathbf{p}^{N,c} + \Delta^c) \right). \quad (2.14)$$

Substituting equation (2.13) into equation (2.14), we obtain the counterpart to equation (2.5). Hence, if the commercial arbitrage constraint is binding, \mathbf{R}^c is affected by the exogenous changes in parameters exactly as \mathbf{R} was when the personal constraint was binding.

3 How Policies Lowering US Drug Prices by the Same Amount Would Affect Manufacturer Profits: A Simulated Comparison

While every policy that lowers retail drug prices in the United States reduces overall manufacturer profits and hence the development of new drugs in the future, some policies reduce profits less than others. We now consider three policies adjusted to lower the US price (p^U) by the same amount and determine which of them reduces manufacturer profits (R) and hence innovation the least.

The three policies are (1) mandating that Medicare either negotiate like foreign governments or pay the price they negotiate, (2) legalizing commercial arbitrage, and (3) promoting online purchases for personal

use from foreign pharmacies licensed in high income countries and deemed safe. As Figure 2.2 illustrates, if policies (2) and (3) are set to achieve the same US price (\mathbf{p}^U), they will induce the same negotiated price (\mathbf{p}^N). This follows since the equilibrium occurs where the lower envelope of the two upward-sloping arbitrage lines, one of which shifts down depending on the policy, intersects the unshifted downward-sloping manufacturer-acceptance line at the given US price (\mathbf{p}^U). Since both policies result in the same US price, both result in the same foreign price (\mathbf{p}^N). Moreover, since revenue per manufacturer is the same function of the foreign price under the two policies, both reduce manufacturer revenue (\mathbf{R} or \mathbf{R}^c , respectively) by the same amount.

By design, all three policies are set to reduce the US price by the same amount. Under policies (2) and (3), massive arbitrage would occur if manufacturers did not *raise* the foreign negotiated price (\mathbf{p}^N) to deter arbitrage. In contrast, policy (1), which increases the bargaining power of the negotiator, forces manufacturers to *lower* the foreign price (\mathbf{p}^N). One might anticipate that the policy that *lowers* the foreign price will reduce manufacturer revenue more than the two policies that raise that price. We illustrate this proposition with a simulation calibrated to the market for HCV cures and defer its proof until the next section.

We assume that retail demand in the United States is a linear function of the retail price ($D(p) = a - mp$) and that the exogenous parameters take on the following values:³¹

- $W = 7$ million
- $Q^N = 5$ million
- $a = 2$ million
- $n = 4$
- $\tau = 1.85$
- $m = .5$
- $\Delta = \$10$ thousand

Because US demand is assumed to be linear, equation (2.3) simplifies to a quadratic in the variable p^N :

$$\tau n p^N Q^N + (\tau p^N + \Delta)(a - m[\tau p^N + \Delta]) = \frac{na^2}{m(n+1)^2} \quad (3.1)$$

\mathbf{p}^N is the smaller of the quadratic's two roots, provided that root is nonnegative; in that case, the markets are connected. If the smaller root is negative, the markets are unconnected and $\mathbf{p}^N = 0$.

In the simulated equilibrium, the US retail price is \$67,380. To reduce it by 10% by mandating that Medicare negotiate like foreign governments or pay the price they negotiate lowers profit per manufacturer by 12.83%. To reduce the retail price by 10% by identifying foreign pharmacies safe for engaging in personal arbitrage (reducing Δ) lowers profit per manufacturer by only 2.3%. The same 2.3% decrease could be achieved by legalizing commercial arbitrage or penalizing it less (lowering Δ^c to achieve the

³¹The first three numbers are based on the WHO Global Hepatitis Report, 2017). The number of manufacturers selling perfect substitutes reflects the four drugs that target genotypes 1-4 of HCV. The assumed markup is based on Sood et al (2017). The slope parameter has been set to generate retail prices roughly consistent with observation.

10% cut in the retail price). If m is changed, these numbers change slightly, but it remains true that the percentage reduction in profit per manufacturer is more than five times as large under the policy of harnessing Medicare's buyer power as under either of the other two policies.

4 More General Results

To this point, I have developed an arbitrage-deterrence model consistent with the three stylized facts noted at the outset. In this section, I want to prove two results that hold not only in this model but more generally. The first compares two policies to lower the US retail price to the same level and shows that one policy achieves this goal with less reduction in manufacturer profits. Losses in manufacturer profits ultimately lead to reductions in long-term innovation. The second result compares two policies to restore long-term innovation when manufacturer profits have been reduced and shows that one policy achieves this goal with less cost to the government.

4.1 A Comparison of Two Ways to Lower US Retail Prices: Promoting Arbitrage versus Tying the Medicare Price to the Foreign Negotiated Price

In the last section, we simulated our model under the assumption of linear US demand and discovered that promoting arbitrage to lower the US price by a given amount reduces manufacturer revenue by less than tying the Medicare price to the foreign price.

We now show analytically that this is a general result: it holds not only in our model but more generally, regardless of the curvature of demand.

Denote the final price in the US market after either policy is adopted as p^U , the price in the negotiated market if arbitrage is promoted as $p^{N,Arb}$ and the price in the negotiated market if Medicare pays $p^{N,Med}$.

Since each policy is adjusted so that the US price falls to the same level, the same number of US patients who could not afford medicine at the higher retail price would now purchase at the reduced retail price. Denote the number of additional cures purchased at the reduced US retail price as j .

Let y denote the number of cures that would *continue* to be acquired by individuals at the reduced US retail price under the two policies.

Let h denote the number of cures that would be acquired by Medicare at the retail price if the policy pursued was to promote arbitrage but at the international price if the policy pursued was tying the Medicare price to the foreign price.

Then if the government promotes arbitrage to lower the US price, manufacturer revenue from the two markets will be:

$$p^U \cdot (y + j + h) + p^{N,Arb} \cdot (Q^N).$$

On the other hand, if the price Medicare pays is tied to the negotiated foreign price, manufacturer revenue from the two markets will be:

$$p^U \cdot (y + j) + p^{N,Med} \cdot (Q^N + h).$$

To verify that manufacturers' revenue from the former policy strictly exceeds their revenue from the latter policy, we subtract the second expression from the first and prove that the difference is strictly

positive:

$$(p^U - p^{N,Med}) \cdot (h) + (p^{N,Arb} - p^{N,Med}) \cdot Q^N \stackrel{?}{>} 0. \quad (4.1)$$

The left-hand side of (4.1) is the sum of two terms, each composed of two factors. The first term is strictly positive since it is equal to the savings Medicare would experience by paying the negotiated foreign price instead of the US retail price. The second term is positive if and only if foreigners pay a higher price if arbitrage is promoted than they would pay if instead Medicare paid the foreign price: $p^{N,Arb} \geq p^{N,Med}$. This inequality is obviously true in our model since the foreign price rises when arbitrage is promoted and falls when Medicare pays the foreign price. But it is likely to hold in any model. The prices foreigners pay under the two policies do not even have to change in opposite directions for the second term to be positive.³² Hence, the conclusion that the promotion of arbitrage is superior to allowing Medicare to use its monopsony power seems very general.

To illustrate, suppose $\Delta = \$10$ thousand per cure and arbitrage promotion reduces it to \$5 thousand. Suppose, as a result of this policy the US retail price drops to \$50 thousand per cure, implying that the foreign negotiated retail price becomes \$45 thousand per cure. To simplify, assume no markups ($\tau = 1$).

If instead Medicare paid the international price for enough patients that the US retail price fell by the same amount (to \$50 thousand), then the foreign retail price would be \$40 thousand since Δ would remain unchanged. As a matter of arithmetic, therefore, the foreign negotiated price would be lower than under arbitrage promotion.

This implies that the *revenue* manufacturers receive from sales to foreign governments would also fall by \$5 thousand per cure. So would the revenue manufacturers receive from sales to Medicare at \$40 thousand per cure that it would have made under arbitrage promotion (or, equivalently, if Medicare had continued to pay the domestic retail price) at \$50 thousand per cure.³³ To conclude, therefore, arbitrage promotion accomplishes the same reduction in the US retail price with less reduction in the profits of the manufacturers. Since manufacturer profits would be reduced less, innovation would be reduced less. Moreover, manufacturers in their self interest should object less to the policy of arbitrage promotion.

Although achieving the entire reduction in the US price by arbitrage promotion depresses manufacturer profit the least, it does raise foreign drug prices. If this is deemed politically unacceptable, one could *combine* the two policies. One could lower the US price part way toward \$50 thousand per cure with arbitrage promotion and the rest of the way by tying the Medicare price to the foreign price. Arbitrage promotion would raise the foreign price and the Medicare policy would lower that elevated foreign price. With the proper combination of the two policies, one could reduce the US price to \$50 thousand per cure *without any change in the foreign price*. Of course, manufacturers would earn lower profits than they would if the domestic price was lowered entirely by promoting arbitrage.

³²Of course, the inequality in (4.1) can hold even if the second term is negative provided it is outweighed by the first term.

³³We have omitted mention of two other groups of buyers who are affected by each policy: US patients who could not afford the medication until the retail price was reduced and US patients who would continue to pay the US price after a price reduction achieved by Medicare tying what it pays to the foreign price. Since both of these groups would pay manufacturers the same amounts under either policy, they do not affect the profit comparison and can be ignored.

4.2 A Comparison of Two Ways to Restore Innovation: Subsidizing Research versus Rewarding Discoveries

As Table 2 reflects, policies that lower US drug prices reduce manufacturer profits. No manufacturer would respond by withdrawing its drug from the market, however, since producing the drug has negligible cost. But in the long run, such reductions in profit will lead to less research and fewer new drugs on the market. We clarify why this would happen below and then compare the cost of two ways of preventing this reduction in research and new drugs.

Most discoveries of promising molecules are made by academic researchers, not by drug companies (Shepherd 2018). When a drug company anticipates that acquiring a promising molecule and developing it into a new drug will generate smaller revenue, the company will pay an academic less to acquire it. Anticipating a smaller reward, some academics who would otherwise have committed to search for a promising molecule will choose not to hunt for one.

Assume there are N risk-neutral academics with distinct, strictly positive probabilities of finding a promising molecule if they search for one. Let $p_i > 0$ denote the success probability of academic i , where $p_1 > p_2 \dots > p_N$. We assume that these academics do not differ in other respects. That is, they have the same expected cost of searching for a molecule (denoted C) and the same expected gain if successful (denoted V). Since C includes the cost of setting up a lab and redirecting one's professional activities, we assume that C is *sunk* when the academic initiates his molecule search. An academic will search if and only if $p_i V - C \geq 0$. No one would search if the expected prize were so small ($V < C/p_1$) that it is unattractive even to the academic with the highest success probability; similarly, all N academics would search if the expected prize were so large ($V \geq C/p_N$) that it is attractive even to the academic with the lowest success probability.

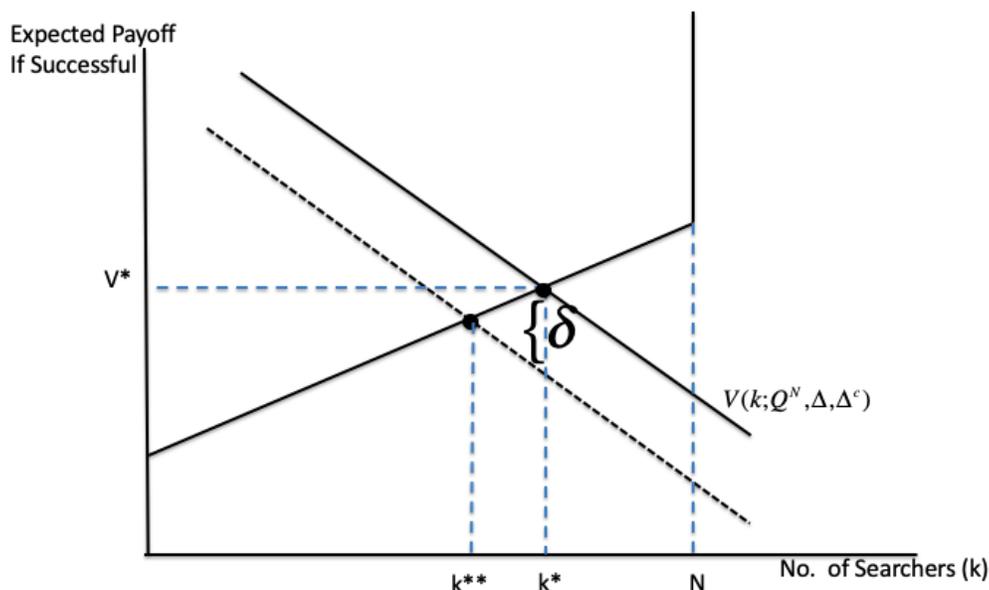
Let k denote the number of academics who commit to searching for a promising molecule. Since k depends on V , we write $k(V)$. Note that $k(V)$ is a step-function.

For $V \in (C/p_1, C/p_N)$ some academics (those with success probabilities weakly higher than C/V) will search for a promising molecule, while those with lower success probabilities will not. If V is reduced enough to alter the number of academics who commit to molecule hunting, those with the lowest probability of success choose another line of work. Hence, $k(V)$ is increasing.

We continue to assume that every FDA-approved drug in this therapeutic class is produced by a different manufacturer. For a fixed number of academic searchers (k), the number of promising molecules they discover is random, and so is the fraction of these molecules that become marketable drugs. Hence, for a fixed k , the reward that manufacturers offer successful academic searchers is random. The expected value (V) of this reward distribution, however, is deterministic. Since academics are assumed to be risk-neutral, only the expected value of the reward distribution affects their behavior. Given our comparative-statics result, V is a decreasing function of k and Q^N and an increasing function of Δ and Δ^c : $V = V(\bar{k}; \bar{Q}^N, \bar{\Delta}, \bar{\Delta}^c)$. If the policy triple (Q^N, Δ, Δ^c) is fixed, an increase in the number of searchers (k) will result in more manufacturers competing on the market, lower profits per manufacturer, and a lower expected payment for a promising molecule.

On the horizontal axis of Figure 4.1, we plot the number of academics who search for a promising molecule. On the vertical axis, we plot the expected reward (V) for the discovery of a promising molecule. The upward-sloping curve depicts the number of academic searchers (k) as a function of the payoff (V)

Figure 4.1: Effect of Reduction in Expected Payoff If Successful on the Number of Academics Searching for a Molecule



they expect to receive if they are successful. Although $k(V)$ is a step-function, we represent it as smooth. The downward-sloping curve is $V(k; Q^N, \Delta, \Delta^c)$.³⁴

Denote the intersection of the two curves as (k^*, V^*) . This intersection point corresponds to the unique equilibrium: exactly k^* academics voluntarily search for molecules because they expect to receive V^* dollars if successful, and manufacturers voluntarily pay each successful academic V^* dollars because of the revenue they anticipate receiving in the product market when k^* academics search for molecules.

Reducing the domestic price by having the FDA identify pharmacies safe for personal arbitrage, by legalizing commercial importation, or by tying what Medicare pays to the foreign price shifts down $V(k; Q^N, \Delta, \Delta^c)$. If the function shifts down, the expected prize (V) would fall. In the short run, the number of researchers committed to hunting for molecules would not change. But in the long run, anticipating that manufacturers would pay less for a promising molecule, searchers with the lowest success probabilities would choose pursuits expected to be more remunerative.

Suppose that in response to reduced revenue in the drug market, each manufacturer reduces its payment for promising molecules by δ . In the short run, the number of manufacturers selling existing drugs and the number of academics searching for new ones will not change since their costs are sunk. But in the long run, the number of academics searching for molecules would drop to k^{**} in Figure 4.1, and fewer promising molecules would be discovered and developed into marketable drugs.

To prevent this, the government could restore the payment to V^* by paying δ to every researcher who finds a promising molecule. In that case, k^* academics would again search for promising molecules.

Alternatively, the government could pay each individual committed to searching for a promising molecule $p_{k^*} \delta$ before the outcome of his research gamble is realized.³⁵ Each committed researcher would

³⁴Our results would not change if the curve were horizontal or even upward-sloping, provided it crosses the supply curve from above.

³⁵It typically takes more than a decade before a molecule clears various preliminary FDA hurdles and is deemed promising enough

then earn $p_i(V - \delta) + p_{k^*}\delta$. Since this equals C for $p_i = p_{k^*}$ and exceeds C for $i < k^*$, the same set of researchers would commit to searching. Which of these policies to restore innovation is cheaper?

The aggregate cost of rewarding only those researchers who discover a promising molecule is a random variable with expected value $(p_1 + p_2 + \dots + p_{k^*})\delta$. The aggregate cost of rewarding every committed researcher before knowing the outcome of his research gamble is certain: $k^*p_{k^*}\delta$

$$k^*p_{k^*}\delta < (p_1 + p_2 + \dots + p_{k^*})\delta. \quad (4.2)$$

The inequality follows because there are k^* terms in the parentheses on the right-hand side, none smaller and at least one strictly larger than p_{k^*} .

The marginal researcher is indifferent whether the government pays him $p_{k^*}\delta$ before the realization of his research gamble or δ if he is successful. But *every* other researcher strictly prefers to receive δ if successful. In fact, since $p_{k^*}\delta - p_i\delta < 0$ for $i = 1, \dots, k^* - 1$, the higher the success probability of inframarginal researcher i , the more he loses if the government pays before, rather than after, the realization of the research gambles. Making payments before the realizations of the research gambles redistributes inframarginal rents from researchers to the government, with those with the highest success probabilities paying the most.³⁶

5 Conclusion

In this paper, we identified three stylized facts about the international market in patented pharmaceuticals that seem undeniable. We then showed that no model in the literature explains these facts, and we constructed a new model consistent with them. Central to this explanation is the effect on manufacturer pricing of the threat of massive personal arbitrage; we can think of no other reason why foreign governments would not have negotiated a price much closer to the marginal cost of production.

We used this arbitrage-deterrence model to predict the effects of several policies: (1) tying the Medicare price to the price foreign governments negotiate, (2) legalizing commercial arbitrage, and (3) promoting online imports from foreign pharmacies requiring prescriptions and licensed in other high income countries. We showed that when each policy is set to achieve the same reduction in the domestic retail price, the loss in manufacturer profits is greater with the tied Medicare price than under the other two policies. This result holds not only in the model of arbitrage deterrence but more generally. Since most models predict that reductions in manufacturer profit per drug depress long-run innovation, we concluded by comparing two ways to restore innovation to its previous level. We showed that in general it is cheaper for the government to restore innovation by subsidizing research than by rewarding the discovery of promising molecules.

to be acquired by a drug company. To avoid paying subsidies to con artists, payments should be deferred until the researcher has set up his/her lab, searched for a promising molecule for several years, and has publicly announced to peers the goal of the research he is conducting.

³⁶Years of research are required to identify a promising molecule. The government should not make any payments to researchers until they have purchased the required laboratory equipment, have hired the appropriate personnel, and have completed preliminary steps in their search for a promising molecule. In this way the government can avoid being duped by a scientist scammer who wishes to use the funds for another purpose.

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