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Bargaining over entry with a compulsory license deadline: Price spillovers and surplus expansion*

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Abstract

We analyze bargaining between a developing country (South) and a multinational firm over the local price of its patented product. We use an alternating offers bargaining game in which the South can resort to compulsory licensing (CL) if the two parties fail to reach agreement by a certain deadline. The presence of international price spillovers introduces two novel features into the standard bargaining problem: (i) the surplus from entry prior to the CL deadline may be negative and (ii) CL can yield higher surplus than entry. We establish conditions under which equilibrium may exhibit immediate entry, preemptive entry just prior to the CL deadline, or the occurrence of CL. The South necessarily gains from the threat of CL if the joint payoff under entry is higher relative to CL but can lose if it is lower.

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1 Introduction

A crucial policy issue confronting low and middle income countries today is how to provide local consumers access to patented foreign medicines at affordable prices. Prior to the mid 90's, such countries could buy generic versions of these products from pharmaceutical companies in countries such as India and China that had fairly weak patent regimes. However, the ratification of the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) in 1995 by the World Trade Organization (WTO) essentially eliminated this option by requiring all WTO members to provide a minimum of 20 years of patent protection. As a result, governments across the world now need to rely primarily on negotiations with patent-holders to obtain price reductions.

During such negotiations, pharmaceutical companies can be unwilling to cut prices of their patented products in developing countries, even when local profits could be made, because of the fear of undermining their ability to sustain higher prices in other countries. There are two reasons why a patent-holder can be concerned about international price spillovers. First, international price discrimination can be undone by the flow of *parallel imports* from low price markets to high price ones. Second, governments of many countries resort to *external reference pricing* when bargaining over prices with pharmaceutical companies or setting their local price controls, a policy under which the prices that they are willing to permit locally depend on prices being charged by firms in *other* countries. This governmental practice can put firms in the awkward position of having to explain why they need to charge high prices in some countries when they find it profitable to sell at low prices in other countries.

Due to the possibility of international price spillovers, pharmaceutical companies may deliberately choose not to serve the local markets of many developing countries. What recourse does a developing country have when it finds itself in such a situation? As it turns out, WTO rules pertaining to intellectual property provide an escape route. When faced with limited or no access to a patented foreign product, a country may resort to *compulsory licensing*, i.e., an authorization granted to

someone other than the patent-holder to produce the patented product without the patent-holder's consent.¹ Our goal in this paper is to analyze how the potential issuance of a compulsory license affects price negotiations between a patent-holder and a developing country.

Motivated by WTO ground rules that govern the use of compulsory licensing (CL) and recent experience with CL (discussed in Section 2.2 below), we develop and analyze an alternating offers bargaining game between a multinational firm and the government of a developing country (called South). In our model, as the sole producer of a patented good, the multinational negotiates with the South over the terms of its entry into the local market. An agreement between the two parties consists of a price charged in the South for the duration of the patent and a lump sum transfer (which can be negative) paid by the multinational. We assume that the two parties have complete information about payoffs and analyze how the threat of CL affects the timing of entry by the multinational and the distribution of surplus between them. We model the WTO rules on CL as providing an exogenously given time at which the South can unilaterally terminate the bargaining problem by issuing a compulsory license, and analyze how this deadline affects the outcome of the bargaining game.

Two fundamental features of our bargaining problem distinguish it from the standard alternating offers bargaining game. The first concerns the amount of (per-period) surplus generated by the entry of the multinational into the Southern market. The loss in profits suffered by the multinational in its home (North) market due to price spillovers from the South raises the possibility that the joint payoff resulting from the firm's entry into the South's market is actually negative. In such a scenario, there exists no price-transfer pair that can make both parties better off if the multinational enters the South. The second crucial feature of our bargaining problem is the difference between the surplus under CL and entry. If the Southern licensee cannot produce a sufficiently high quality version of the patented product,

¹Parallel imports from another low price market would be an option but this would only work if the company does not choose to forsake that other market for the same reason. The freedom to allow parallel imports and the option to use compulsory licensing are widely seen as the two major *flexibilities* available under TRIPS to WTO member countries – see Maskus (2000a and 2000b) for a detailed discussion of these flexibilities.

the payoff generated under CL is lower than that under entry. However, it is also possible that the CL yields a *larger* payoff than entry. To see how this can happen, first note that WTO rules require that sales under a compulsory license should be restricted to the local market of the country issuing the license. Thus, to be compliant with WTO rules, the South has an incentive to discourage any arbitrage trade that can spill over to the multinational's home market. Similarly, any external reference pricing policy on the part of the North cannot reasonably hold the multinational accountable for the price of its product in the South under CL since production and pricing are no longer controlled by it. Thus, by *reducing* the degree of price spillovers between markets, the issuance of a compulsory license has the potential to increase the surplus available to the two parties.

In modeling the bargaining problem, we assume that the South cannot commit to not imposing a compulsory license if the two parties fail to reach agreement by the deadline. In the case where the joint payoff from CL is negative, this assumption prevents the multinational from making a cash transfer to the South in return for the latter agreeing to forgo the use of CL. We believe this assumption is realistic in the context of our model because a contract between the multinational and the South under which the latter agrees to forgo the use of CL would not be enforceable at the WTO. Furthermore, domestic political pressure would likely make it impossible for the Southern government to be able to deny local consumers access to a patented foreign product (such as a pharmaceutical) in return for a cash payment from the patent-holder.

Our results show how the timing of the multinational's entry into the South and the split of the surplus between the two parties is determined by the two basic features of the bargaining problem discussed above. In the case where the surplus generated by entry is positive and exceeds that under a compulsory license, the threat of CL only redistributes surplus from the multinational to the South (provided the threat is credible). If the surplus generated by entry is negative, the multinational cannot pay the country not to issue a CL under our assumptions. Therefore, the firm may make a preemptive offer just prior to the deadline to prevent the imposition of a compulsory license. If this happens, the South benefits at the expense of the

multinational because it obtains a high quality product that would otherwise not have been available to its consumers. In both cases, the payoff to the South is decreasing in the length of the delay period that must elapse before the South is free to issue a compulsory license. Furthermore, CL may be observed in equilibrium, even though it yields lower surplus than entry if the bargaining friction (defined as the time between offers) is sufficiently large.

We find that CL can also arise in equilibrium if it results in a higher payoff than entry *and* the required delay period before it can be implemented is not too long. The latter condition is important because even if the surplus under CL is higher than that under entry, it may not be worth delaying agreement too much to obtain that higher level of surplus. We also show that each party's equilibrium payoff in this case depends on the division of surplus under CL, leading to a variety of possible outcomes. In cases where a compulsory license is imposed in equilibrium, the payoff to the South is decreasing in the delay period before the license can be imposed. The multinational's payoff, on the other hand, can be either increasing or decreasing in the required delay period, depending on its share of total surplus under CL.

An interesting result of our paper is that it is possible for the South to receive a *lower* average payoff in equilibrium when there exists a credible threat of CL relative to what it receives in the absence of such a threat. This paradoxical outcome can only arise when CL yields a higher payoff than entry and the multinational's share of that higher surplus exceeds its share under bargaining (absent the threat of CL). The possibility of the multinational receiving a larger share of the surplus under CL arises if the license provides a substantial royalty payment to the multinational while also leading to an effective segmentation of the Southern market from the Northern one. Under these conditions, the threat of CL can lower the South's equilibrium payoff in one of two ways. First, even though the South earns a higher per period payoff under CL, the payoff starts to accrue only after the license goes into effect. It follows then that the South can be made worse off due to the threat of CL if the delay incurred before it can impose the license is sufficiently long.

The threat of CL can also lower the South's average payoff when the bargaining outcome results in immediate entry provided the two conditions isolated above –

i.e. a larger surplus under CL relative to entry coupled with a larger share for the multinational – continue to hold. The South’s loss in this case arises because the possibility of CL *weakens* its bargaining position. Even though the multinational cannot itself issue a compulsory license, it can delay agreement until the Southern government can do so. In such a situation, the South’s ability to use CL actually shifts bargaining power in *favor* of the multinational. Indeed, when the multinational has an incentive to delay agreement until a compulsory license can be issued, the South would be better off it could pre-commit to not issuing such a license.

Our analysis of price negotiations in the shadow of CL is related to the literature that examines bargaining under a deadline. One strand of this literature deals with the commitment effect of a deadline in a setting where a seller makes offers to a buyer with private information about his valuation of the object. According to the well known Coase Conjecture (e.g. Gul, Sonnenschein, and Wilson (1986)), the inability of the seller to commit to future prices causes its profit to vanish as the time between offers goes to zero. Fuchs and Skrzypacz (2013) analyze the role of deadlines in a bargaining model by introducing an exogenously given deadline at which the players receive a payoff whose total can be no more than the buyer’s valuation if no agreement has been reached.² They show that the seller’s payoff converges to the present value of making a final offer at the deadline as the time between offers goes to zero. Thus, the deadline improves the seller’s bargaining position by putting a bound on the extent to which the seller will cut price in the continuous time limit. Our analysis abstracts from this role of deadlines by assuming that parties have complete information about valuations. In our case, the payoff to the parties in the event of an agreement is the weighted average of the payoff that would be received if the compulsory license is imposed at the deadline and the payoff that would be received in the absence of a deadline.

A second focus of the literature on deadlines is the effect of deadlines on the timing of agreements. Fuchs and Skrzypacz (2013) show that the existence of a deadline results in a mass of agreements being reached at the deadline, in order to avoid the

²Their model is an extension of the Sobel and Takahashi (1987) model of multistage bargaining, which assumes that players receive zero payoffs if there is no agreement by the deadline.

shrinkage in payoff that arises if no agreement is reached. Spier (1992) considers the problem of pretrial negotiation, where a plaintiff makes offers to a defendant with private information about the size of damages. In her model, the two sides often fail to reach agreement and when settlement takes place, it usually does so quite close to the deadline. Introducing fixed costs of bargaining into the model delivers a U shaped pattern of settlement, i.e., there is greater chance that the two parties reach agreement at the beginning or at the end of negotiations relative to the middle. Spier (1992) also considers the case in which the plaintiff has the option of choosing the time at which to go to trial, so that the deadline is endogenously determined.

In our model, the full information assumption means that if an agreement on entry is reached, it will either occur immediately or right before the deadline. The latter case arises if CL reduces the total payoff and bargaining frictions are sufficiently small. The possibility that the joint payoff increases under a compulsory license also means that it can be in the interest of both parties to have the license imposed, which can result in a delay in the serving of the Southern market relative to the case where a compulsory license cannot be issued.

The rest of the paper is organized as follows. In section 2, we provide a brief discussion of the empirical evidence that motivates our model. Section 3 presents our bargaining game and derives its equilibrium when CL is not an available option for the South. Section 4 introduces CL and analyzes how it affects equilibrium outcomes and welfare. Section 5 contains some concluding remarks.

2 Empirical relevance of the model

This section discusses the key empirical facts motivating our model. First, we summarize the relevant findings of the empirical literature on international price spillovers arising from parallel imports and the governmental practice of external reference pricing. Next, we provide a brief discussion of the WTO rules on compulsory licensing and discuss some recent CL episodes to illustrate the role of CL in the bargaining process.

2.1 International price spillovers

A number of empirical studies have shown that new pharmaceutical products are not launched or experience substantial launch delays in markets where income levels are low and where there are price controls.³ Not only do these factors lead to lower prices and profits in that particular market, they can also affect profitability in other markets. For example, Kyle (2007) studied drug launches in the 28 largest pharmaceutical markets from 1980-2000 and found that a country's use of price controls not only delays drug launches into its own market, but also lowers prices that *other* countries are willing to pay.⁴

An important channel of international spillovers is the policy of external reference pricing, under which a country uses the prices at which products are sold in other markets in setting the regulated prices for its own market. Ruggeri and Nolte (2013) report that 24 of 27 European countries use international price comparisons in negotiating prices with pharmaceutical companies, with the number of comparison countries ranging from 5 to 20. They also note that this policy is used by numerous countries outside Europe, including Brazil, South Africa, Australia, and Canada. Even in countries where reference pricing is not an explicit policy, the presence of low prices in other markets can generate public pressure for price reductions. For example, high prices of pharmaceuticals in the US relative to the rest of the world frequently stirs up debate and discussion in the US press as well as the Congress.⁵ As Goldberg (2010) notes, by delaying access to drugs or denying it altogether, reference pricing policies in high-price countries impose welfare costs on low-price countries and

³Danzon et. al. (2005) studied launch data during 1994-1998 pertaining to 85 new chemical entities in 25 major markets and found that only about half of all potential launches actually occurred. Countries with lower prices or smaller markets size experienced fewer launches and longer launch delays. Danzon and Epstein (2008) studied drug launches in 15 countries during the period 1992-2003, found that drug launch in low-price EU countries was adversely affected by prior launch in high-price EU countries.

⁴Similar evidence emerges from Lanjouw's (2005) extensive study of drug launches in 69 countries of varying income levels during 1982-2002.

⁵A discussion of a few of these incidents is available in Pecorino (2002) and Roy and Saggi (2012). See also the recent report by the USTR on US international frictions related to intellectual property rights: *2013 Special 301 Report*.

can potentially justify the use of CL on their part.

A second channel for price spillovers is the existence of parallel trade. The EU allows free flow of parallel imports within its territory, which puts a limit on the extent to which firms can price discriminate between EU countries. By some estimates, such trade accounts for about 10% of the total EU market for pharmaceuticals.⁶ As one might expect, parallel trade within the EU generally flows from low price markets such as Greece and Spain to high price markets such as Germany, UK, Netherlands, and the Scandinavian region. Ganslandt and Maskus (2004) found that after Sweden joined the EU and opened its pharmaceutical market to parallel imports, prices of drugs that were subject to competition from parallel trade declined 12-19%.⁷ Such trade is not legal between most developed and developing countries, but illegal trade still has the potential to arise if there are substantial price differences between markets. For example, it is well known that the presence of price controls in Canada creates incentives for the illegal importation of pharmaceuticals into the US from Canada.

2.2 Price negotiations and compulsory licensing

Article 31 of TRIPS lays down rules that govern the use of CL by WTO member countries. In addition to the requirement that a compulsory license can be issued only if the patent is not worked locally, these rules require that CL “may only be permitted if, prior to such use, the proposed user has made efforts to obtain authorization from the right holder on reasonable commercial terms and conditions and that such efforts have not been successful within a reasonable period of time.”⁸ Article 31 also requires

⁶See “European drug groups fear parallel trade” *Financial Times*, June 7, 2010.

⁷Note that the mere possibility that such trade can arise puts limits on the ability of firms to engage in international price discrimination. This implies that the observed price declines and the volume of parallel trade are likely to underestimate the true impact of the possibility of parallel trade on the pricing behavior of firms.

⁸The WTO does not provide a minimum time required to pass before a compulsory license can be applied for. However, it does require that the standards of the Paris Convention on Industrial property be adhere to. Article 5 of the Paris convention specified a minimum time period of four years from the application for a patent or three years from the granting of a patent, whichever is greater.

that “adequate remuneration in the circumstances of each case, taking into account the economic value of the authorization” must be paid to the patent-holder and that the compulsory license “shall be authorized predominantly for the supply of the domestic market of the Member authorizing such use”. The 2001 Doha Ministerial conference expanded these powers by allowing compulsory licenses to be issued to producers in third countries in order to make CL accessible to those countries that lacked the capability to produce pharmaceutical products domestically.

In addition to providing a means for countries to obtain access to a patented product when the local market is not being served, the TRIPS agreement also grants certain protections to patent-holders. For example, countries issuing a compulsory license must provide a means for patent-holders to have the ability to challenge a compulsory license. More importantly, Ho (2011, Ch 5) notes that, in the event of CL, the home country of the patent-holder can challenge the compulsory license before the Dispute Settlement Body (DSB) of the WTO. Since the DSB has the potential to authorize trade sanctions as remedies against countries that fail to honor their WTO obligations, it provides an external enforcement mechanism that can help prevent violations of the various WTO clauses governing CL such as providing compensation to patent-holders and preventing export sales of products produced under CL.⁹

From the ratification of TRIPS in 1995 to 2011 there have been 24 international episodes where negotiations between developing countries and pharmaceutical companies proceeded to the point where CL was publicly considered or implemented. These episodes involved public officials and/or governments of 17 WTO members and covered 40 drug patents and 22 pharmaceuticals (Beall and Kuhn, 2012). About half of these episodes ended up with the issuance of a compulsory license while nine of them resulted in significant price reductions and can be interpreted as a successful bargaining outcome between pharmaceutical companies and developing countries. In cases where compulsory license were issued, patent-holders received royalties ranging from 0.5% of the generic price to 2% of revenues from the sale of the product.¹⁰

⁹Although there have been no complaints to the DSB involving compulsory licenses so far, the TRIPS agreement as a whole has been cited in 34 complaints.

¹⁰The World Health Organization (2005) provides guidelines for calculating royalty rates for compulsory licenses. These royalty rates for CL are substantially below those from voluntary

These cases illustrate the role CL plays in negotiations between multinationals and developing countries. In some cases, the threat of a compulsory license served as an effective means of negotiating a lower price for the product, while in others the result was the issuance of a compulsory license. Brazil's experience with negotiations over the price of AIDS drugs provides examples of both cases. Brazil's Health Minister threatened CL of nelfinavir (one of the twelve drugs used by the health ministry to combat HIV/AIDS) when price negotiations with Roche, the manufacturer of the drug, ran into difficulties. While price negotiations were ongoing, publicly visible efforts were made by Brazil to prepare Farmanguinhos – the leading government owned pharmaceutical manufacturer – to initiate local production of the drug. In response, Roche agreed to reduce the price of nelfinavir by 40%, an offer that Brazil accepted. Similarly, Brazil threatened the CL of Kaletra, an HIV/AIDS medicine produced by Abbott but never actually implemented the threat since Abbott agreed to reduce the annual per patient cost of Kaletra by a substantial amount. Emboldened by its success with Abbott and Roche, Brazil negotiated fairly aggressively with Merck over the price of Efavirenz, another patented AIDS drug. Interestingly, do Nascimento (2010) notes that during these price negotiations the Brazilian government explicitly used external reference pricing as a strategy by noting that Merck was selling Efavirenz for relatively lower prices in some other middle income countries. These negotiations over Merck's price eventually broke down and ended with Brazil issuing a five-year compulsory license for Efavirenz, with Merck receiving a royalty of 1.5% on local sales of the drug.

These examples illustrate that in some cases the threat of CL results in a preemptive offer by the patent-holder to deter the issuance of a compulsory license, while in other cases the patent-holder prefers to allow a compulsory license to be issued rather than agree to further price reductions. Existing evidence also shows that the quality of the product provided by a potential licensee is a major concern in the implementation of CL, since it may take time to develop the technology to produce

licenses, which typically average around 5%. This gap between the two types of royalties probably reflects the difference between the TRIPS mandated "adequate remuneration" that must be paid to the patent-holder under a compulsory license and the "reasonable commercial terms" of a market-based voluntary license issued by the patent-holder.

the product and generic versions may not be equivalent to the patented products.¹¹

3 Model

We consider a multinational firm that has two markets for its patented product, North and South. The patent has a finite duration (T) during which the multinational has a monopoly over the product in both markets. Motivated by the empirical evidence discussed in the previous section, we examine the entry and pricing decisions of the multinational for the Southern market when there are spillovers between the two markets and the multinational negotiates the terms of its entry with the Southern government.

There is a continuum of Southern consumers, whose measure is normalized to 1. Each consumer buys (at most) one unit of the product at each point in time. If a consumer buys the good at price p , utility is given by $U = \theta q - p$ where q measures quality and $\theta \geq 0$ is a taste parameter that captures the willingness to pay for quality. For simplicity, we assume that θ is uniformly distributed over the interval $[0,1]$ in the South, which yields the demand function $d^S(p^S, q) = 1 - \frac{p^S}{q}$ for the patented good. Northern consumers value quality relatively more than Southern ones in that the preference parameter θ is uniformly distributed over the interval $[0, m]$, with $m > 1$. Assuming a mass of $n \geq 1$ consumers in the North, demand in the North is $d^N(p^N, q) = \frac{n}{m} \left(m - \frac{p^N}{q} \right)$. This specification of market demand allows for greater profitability of the Northern market in terms of the distribution of willingness to pay, as captured by m , as well as the scale of the market, n .

The multinational has a constant marginal cost for selling in each market, which we normalize to 0, yielding profits $\pi^j = p^j d^j(p^j, q)$ for market $j = N, S$. With perfect market segmentation and complete flexibility to price in each market, the multinational maximize profits by charging a price $\hat{p}^S = q/2$ in the South and $\hat{p}^N = mq/2$ in the North. Profits in the respective markets with perfect market segmentation are $\hat{\pi}^S = q/4$ and $\hat{\pi}^N = mnq/4$.

¹¹See Lybecker and Fowler (2009), Daemmrich and Musacchio (2011), and Harris (2014).

We assume that the North follows a policy of national exhaustion under which parallel imports from the South are prohibited, but we allow for some degree of arbitrage between markets that prevent the multinational from engaging in perfect market segmentation. We assume that for all values of p^S at which there are sales in the South (i.e. $p^S < q$), the price in the North is subject to the no arbitrage constraint: $p^N \leq kp^S$. This no arbitrage condition would arise if the detection of parallel imports were to be imperfect, as is likely to be the case in the real world. If δ denotes the probability that a seller engaged in arbitrage is caught and has its products confiscated, then $k = \frac{1}{1-\delta}$ captures the degree to which the Southern price spills over to (or constrains) the price in the North. The no arbitrage condition will bind for $p^S < \min[\frac{mq}{2k}, q]$, so we can express the multinational's global profits as follows:

$$\pi^G(p^S, q) = \begin{cases} \frac{kn p^S}{m} \left(m - \frac{kp^S}{q} \right) + p^S \left(1 - \frac{p^S}{q} \right) & \text{if } p^S < \min \left[\frac{mq}{2k}, q \right] \\ \frac{mnq}{4} + p^S \max \left[\left(1 - \frac{p^S}{q} \right), 0 \right] & \text{if } p^S \geq \min \left[\frac{mq}{2k}, q \right] \end{cases} \quad (1)$$

The international pricing spillover exists as long as the Southern price is less than $\frac{mq}{2k}$, which is more likely to occur the lower the probability of detection of parallel trade and the greater the choke price in the North.

A similar specification of the global profit function arises if the North follows an external reference pricing policy for the patented product. Under the reference pricing interpretation, the parameter k is inversely related to the responsiveness of the North's pricing policy to changes in the Southern price. In this case the spillover will exist as long as the Southern price is below a threshold level given by the North's reference pricing scheme.¹²

¹²Our treatment of reference pricing treats it as an exogenously given rule in the bargaining between the multinational and South. While it would be interesting to endogenize the reference pricing rule, we feel that it would require making marginal cost the private information of the multinational. One of our objectives in this paper is to illustrate that the structure of CL introduces some novel features into the bargaining problem even in the full information case. Endogenizing the reference pricing rule remains an issue for future work.

3.1 The bargaining problem

We assume that the multinational negotiates with the South over the terms of its entry into the local market, with an agreement consisting of a price $p^S \in [0, q)$ to be charged in the South for the duration of the patent and a lump sum transfer to be paid by the multinational (which could be negative).¹³ An agreement yields a per period consumer surplus to the South of

$$S(p^S, q) = \frac{(q - p^S)^2}{2q} \quad (2)$$

and a per period global profit to the multinational of $\pi^G(p^S, q)$.

For $p^S \in [0, q)$, there are positive sales in the Southern market and an agreement over entry generates a joint per period payoff of

$$v(p^S, q) = S(p^S, q) + \pi^G(p^S) \quad (3)$$

to the two parties. We treat time as continuous, so $v_E = \sup_{p^S < q} v(p^S, q)$ denotes the maximum flow of returns to the two parties created by an agreement over the multinational's entry into the South.

If no agreement is reached, the multinational stays out of the South. The multinational earns a disagreement flow payoff equal to the optimal monopoly profit, $\hat{\pi}^N$, in the Northern market while the South gets nothing. We can then define the flow of joint surplus from an agreement, which is the difference between the maximum agreement payoff and disagreement payoff, as

$$\gamma_E = v_E - \hat{\pi}^N \quad (4)$$

It is straightforward to show that γ_E is decreasing in m and n when the arbitrage constraint binds, since the multinational's loss in profits in the North from entering the South is greater when the Northern market is more profitable. Similarly, a larger

¹³After the expiration of the patent, the good is assumed to be available at a competitive price in both markets so that an agreement between the two parties generates no additional surplus.

impact of a price reduction in the South on the Northern price (i.e. smaller value of k) reduces γ_E .

If the price spillover between markets is significant and the Northern market is sufficiently profitable, the price reduction required in the Northern market in order to sell in the South is so large that $\gamma_E < 0$. The following Lemma provides a characterization of the entry and pricing decisions that maximize the joint payoff under entry (proofs of results are in the Appendix):

Lemma 1 *There exists $m^* \equiv \frac{1+\sqrt{1+(2nk)^2}}{n}$ such that*

(i) for $m \leq m^$, $\gamma_E \geq 0$ and the joint payoff $v(p^S, q)$ is maximized by selling in the Southern market at a price*

$$\tilde{p} = \frac{mnqk}{2nk^2 + m}, \quad (5)$$

(ii) for $m > m^$, $\gamma_E < 0$*

As a benchmark, we first examine the solution to the bargaining problem between the multinational and the South when CL is not an option. We assume that negotiations between the multinational and the South can be described by an alternating offers bargaining game, which has a finite horizon determined by the expiration of the patent at time T . Letting D denote the time between offers, period i of the bargaining game begins at calendar time iD . The magnitude of D can be interpreted as the amount of friction in the bargaining process.

Letting $N = \frac{T}{D}$ be the number of offers that occur before the patent expires, we have offers occurring at times $\{0, D, 2D, \dots, (N-1)D\}$. Following Rubinstein (1982), we solve for the subgame perfect equilibrium in the bargaining game. The proposer in period $i \in \{0, \dots, N-1\}$ makes an offer that makes the responder indifferent between accepting the offer and waiting to be the proposer in the next period. A delay in reaching a agreement for one period results in a loss of $\gamma_E(1 - e^{-rD})/r$. Using backward induction arguments, we obtain the standard result that an agreement is reached immediately if entry yields a non-negative surplus. In light of our assumption of a finite horizon for the life of the patent, the exact split of the surplus between

the two parties depends on which party moves first and which last. If $N = 1$ (i.e. $D = T$), the proposer captures all of the surplus by making a take it or leave it offer that makes the respondent indifferent between accepting and rejecting. As the time between offers (i.e. D) decreases, the order of moves becomes less important and payoffs approach an even split of the surplus between the two parties. Since we have no a priori reason to assume a particular order of moves, we report payoffs for the limiting case of $D \rightarrow 0$ in which payoffs are not sensitive to assumptions about the order and number of moves.¹⁴ We can now state:

Proposition 1 *The equilibrium of the alternating offers bargaining game has the following characteristics:*

(i) *If $\gamma_E \geq 0$, an agreement is reached in the first period and the multinational sells the product in the Southern market at price \tilde{p} . The multinational's average payoff in the limiting case as $D \rightarrow 0$ is $\hat{\pi}^N + \frac{\gamma_E}{2}$ while that of the South is $\frac{\gamma_E}{2}$.*

(ii) *If $\gamma_E < 0$, no agreement is reached and the multinational does not sell in the South. In this case, the multinational obtains an average payoff of $\hat{\pi}^N$ while the South receives a payoff of zero.*

The alternating offers bargaining game yields an efficient outcome from the viewpoint of the total payoff of the two parties, since entry occurs only when it generates a joint surplus (i.e. $\gamma_E \geq 0$) and it occurs without delay. The efficient price is chosen because it is in the interest of both parties to maximize joint surplus given that a lump sum transfer is available to shift surplus between them. The limiting case eliminates any advantages derived from the order of moves, so the surplus is evenly split between the parties. Entry fails to occur when the Northern market is sufficiently profitable relative to the Southern one and/or the price spillover across markets is large. As we noted in section 2, there is strong support for this result in the relevant empirical literature.¹⁵

¹⁴This prevents us from having to present expressions for cases with both odd and even numbered periods, which differ due to our assumption of a finite horizon. This issue, as well as the first mover advantage, disappears as D becomes arbitrarily small.

¹⁵The assumption that the payoff in the North market is constant in all periods leads to the result

4 Bargaining under threat of compulsory licensing

We now extend the model to allow for the possibility of CL. Suppose that if an agreement has not been reached by time $T_{CL} < T$, the South can impose a compulsory license in the next period. The time period T_{CL} captures the WTO rule that the patent-holder must be given a reasonable period of time to work its patent before a government can issue a compulsory license to another entity.

Under CL, a domestic firm produces the patented product at marginal cost zero but its quality q_{CL} is lower than that of the multinational ($q_{CL} \leq q$). Furthermore, the Southern government specifies the price at which the local firm must sell the product locally and it pays a per-period royalty R to the multinational. We treat R as an exogenously given parameter reflecting the WTO specified obligation of providing reasonable compensation to the patent-holder for the use of its patent.

Under CL, the Southern government chooses the local price to maximize the sum of consumer surplus and profits of the domestic firm:

$$\underset{p}{Max} \quad \frac{(p - q_{CL})^2}{2q_{CL}} + \pi^S(p, q_{CL})$$

Southern welfare under CL is maximized by setting price equal to marginal cost, which yields a per period payoff of

$$w_{CL}^S = \frac{q_{CL}}{2} - R \tag{6}$$

The price under CL equals marginal cost because the South is not required to compensate the multinational for any lost profits in the Northern market. The flow payoff to the multinational under a compulsory license consists of the profits earned

that if entry occurs, it must occur in the first period. If the magnitude of the price spillover to the North market is declining over time, as might happen if there is entry of competing products, then entry might occur with delay if γ_E switches from a negative to a positive value over time.

in the Northern market plus the royalty payment from the license:

$$w_{CL}^M = \frac{np_{CL}^N}{m} \left(m - \frac{p_{CL}^N}{q} \right) + R$$

where p_{CL}^N is the price that the multinational is able to maintain in the Northern market when the compulsory license is granted. If pricing spillovers across markets are completely eliminated under CL, then we must have $p_{CL}^N = \hat{p}^N$. In general, we will have $p_{CL}^N \leq \hat{p}^N$. The sum of the two parties' flow payoffs under CL is

$$v_{CL} = w_{CL}^S + w_{CL}^M$$

Denote the difference between the joint payoff under CL and the joint payoff under entry by $\gamma_{CL} \equiv v_{CL} - v_E$, which can be expressed as

$$\gamma_{CL} = \frac{1}{2} \left[q_{CL} - q \left(1 - \frac{\tilde{p}}{q} \right) \right] + \frac{n}{m} \left[\left(m - \frac{p_{CL}^N}{q} \right) p_{CL}^N - \left(m - \frac{k\tilde{p}}{q} \right) k\tilde{p} \right] \quad (7)$$

The first term in square brackets is the difference between the sum of profits and consumer surplus in the Southern market under CL and entry. This term shows that CL has two conflicting effects in the Southern market. It reduces the price at which the South obtains access to the product, but it also may result in a lower quality product being sold in the South. CL increases the sum of producer and consumer surplus in the South as long as the quality of the licensee's product satisfies

$$\frac{q_{CL}}{q} > \left(1 - \frac{\tilde{p}}{q} \right)$$

The above inequality is more likely to be satisfied the more profitable is the Northern market (as reflected in a higher bargained price under entry, \tilde{p}).

The second term in (7) measures the difference in profits in the Northern market between CL and entry. If the reduced price in the South market under CL lowers price in the Northern market, then the multinational's profit in the North market is reduced due to CL. The adverse impact of a compulsory license on North profits is

mitigated if CL reduces the magnitude of the price spillover, and could even result in an increase in global profits earned by the multinational if it is able to sustain its monopoly price in the Northern market under CL. There is good reason to believe that the issuing of a compulsory license reduces the scope of international price spillovers. This is because WTO rules governing CL require that the output under a compulsory license be sold only in the domestic market. The existence of this geographical restriction, combined with the potential for a WTO dispute in case the restriction is violated, is likely to serve as a commitment mechanism that allows the South to make credible promises to restrict price spillovers to the Northern market. Such promises may not be credible in the absence of WTO obligations. Similarly, a compulsory license is also likely to reduce the likelihood that the multinational is constrained by an external reference pricing policy on the part of the North since under CL it is the Southern government that controls the price and production of the good as opposed to the multinational. As a result, the local price in the South under CL is unlikely to be viewed as one at which the multinational voluntarily agreed to sell in the South. Indeed, as per WTO rules, a government is authorized to use CL precisely when a patent-holder *refuses* to work its patent in the local market. If the quality of the licensee's product is very close to that of the multinational and CL is effective in eliminating arbitrage we must have $\gamma_{CL} > 0$, in which case CL increases the joint payoff relative to entry. Thus, in what follows, we allow γ_{CL} to be either positive or negative.

4.1 Equilibrium entry under compulsory licensing

We begin our analysis of the alternating offers bargaining game by considering the decision of the South regarding whether to grant a compulsory license. We assume that the South can only issue a compulsory license when it is its turn to make a proposal. In any period after T_{CL} at which it is the South's turn to make an offer, it must decide whether to issue a compulsory license or to continue bargaining with the multinational. If the average payoff under CL, w_{CL}^S , exceeds the average payoff it can earn by continuing to bargain, then it will end the bargaining game and issue

a compulsory license. Otherwise it will continue to bargain.

We make two assumptions concerning the bargaining game with threat of a CL. The first simply limits attention to cases where the CL is a credible threat for the South.

Assumption 1 (*Credible CL*) *The payoff to the South under the compulsory license exceeds its payoff if it were to continue bargaining with the multinational at T_{CL} . In the limiting case as $D \rightarrow 0$, this assumption requires $w_{CL}^S > \max[\frac{\gamma_E}{2}, 0] \Leftrightarrow \frac{q_{CL}}{2} > R + \max\{\frac{\gamma_E}{2}, 0\}$.*

Compulsory licensing is a credible threat for the South if the quality of the licensee's product is not too low or the required royalty payment R to the multinational is not too high. Under Assumption 1, the bargaining game ends at the South's first opportunity to move after T_{CL} . Letting N_{CL} be the smallest integer greater than T_{CL}/D at which it is the South's turn to move, bargaining offers can be made at calendar times $\{0, D, 2D, \dots, (N_{CL} - 1)D\}$ before the CL decision is made. If the South rejects the multinational's offer in period $N_{CL} - 1$, the game terminates with the issuance of a compulsory license. As in the benchmark bargaining game without CL, an offer consists of a price for the product and a net transfer to be paid to the multinational if it enters the Southern market.

Our second assumption is more substantive, in that it restricts the types of agreements that can be struck between the two parties.

Assumption 2 (*no CL buyout*): *The South cannot give up its right to issue a compulsory license in return for a cash transfer from the multinational.*

We impose this assumption because we do not believe that an agreement that allows the multinational to "buy out" the South's right to issue a compulsory license can arise in the real world due to two reasons. First, it seems unlikely that a multinational firm would be able to enforce such an agreement if a developing country were to renege on its commitment once it had reached the time at which it can issue a compulsory license. Such an agreement between a multinational and a developing

country government would be unenforceable at the WTO because WTO treaties are contracts between sovereign nations. Private agents (individuals or firms) have no standing at the WTO. Thus, any agreement between a multinational and a developing country over the latter agreeing to give up its right to issue a compulsory license cannot be interpreted as a WTO obligation. Furthermore, for obvious reasons, such an agreement would also be difficult to enforce in a domestic court of a developing country. A second reason as to why such an agreement between the two parties may be infeasible in the real world is that the government of a developing country would likely find it politically unpalatable to enter into an agreement under which it deliberately agrees to deny local consumers access to a patented product (such as an AIDS medicine) in return for a cash transfer from a multinational. Furthermore, any transfers made to the government would be unlikely to reach those most in need of the patented product, making the agreement politically unpopular. In fact, governments in developing countries generally face significant public pressure from citizens, public interest watch groups, and non-governmental organizations to improve local access to patented pharmaceuticals. Nevertheless, for the sake of completeness, in section 4.4 we discuss the effects of relaxing Assumption 2.

In analyzing the bargaining game, we first identify the entry decision for periods $i = 0, \dots, N_{CL} - 1$ that maximizes the total payoff to the two parties over the duration of the patent, given the threat of CL at $N_{CL} - 1$ if no agreement has been reached by that time. We then show that the solution to the bargaining problem results in the entry time that maximizes this total payoff.

The present value payoff to the two parties at time 0 if the multinational enters in period i equals

$$V_0^E(i) = [\hat{\pi}^N (1 - e^{-rDi}) + v_E (e^{-rDi} - e^{-rDN})] / r \quad i = 1, \dots, N_{CL} - 1 \quad (8)$$

The payoff to entry at time i is the sum of the return from sales in the North market only for $i = 0, \dots, i - 1$ and sales in both markets from i until the end of the patent. Since $rV_0^E(i) - V_0^E(i - 1) = -\gamma_E(e^{-rD(i-1)} - e^{-rDi})/r$, the total payoff from entry will be maximized by entry at time 0 if $\gamma_E > 0$ and at time $N_{CL} - 1$ if $\gamma_E < 0$. The

joint payoff to the two parties time 0 of waiting for a compulsory license is

$$V_0^{CL} = [\hat{\pi}^N (1 - e^{-rDN_{CL}}) + v_{CL} (e^{-rDN_{CL}} - e^{-rDN})] / r \quad (9)$$

The payoff from waiting for CL depends on both the flow payoffs under CL and the North market profits earned during the delay period preceding the compulsory license.

The payoff maximizing policy is obtained by comparison of $V_0^E(0)$ and V_0^{CL} if $\gamma_E > 0$ and a comparison of $V_0^E(N_{CL} - 1)$ and V_0^{CL} if $\gamma_E < 0$. This yields the following result:

Proposition 2 *The joint payoff maximizing regime, subject to the "no CL buyout" assumption, takes the following form:*

- (a) For $\gamma_{CL} < 0$ and $\gamma_E \geq 0$, the multinational should enter at $i = 0$.
- (b) For $\gamma_{CL} < 0$ and $\gamma_E < 0$, entry should occur in period $N_{CL} - 1$ if

$$\begin{aligned} r(V_0^E(N_{CL} - 1) - V_0^{CL}) = & \gamma_E(e^{-rD(N_{CL}-1)} - e^{-rDN_{CL}}) \\ & - \gamma_{CL}(e^{-rN_{CL}D} - e^{-rND}) \geq 0 \end{aligned} \quad (10)$$

Otherwise a CL is issued. (10) must be satisfied for D sufficiently small.

(c) For $\gamma_{CL} \geq 0$ and $\gamma_E \geq 0$, there exists a critical time $\hat{T} \in [0, T_{CL}]$ such that the multinational should enter at $i = 0$ if $DN_{CL} \geq \hat{T}$ and wait for a compulsory license otherwise. \hat{T} is the solution to

$$\gamma_E(1 - e^{-r\hat{T}}) - \gamma_{CL}(e^{-r\hat{T}} - e^{-rND}) = 0 \quad (11)$$

- (d) For $\gamma_{CL} \geq 0$ and $\gamma_E < 0$, a compulsory license should be issued.

The question of whether entry or CL yields higher total payoff depends on a comparison of the discounted joint surplus from entry prior to the issuance of a CL and the flow payoff differential during the period when CL would be in effect. When γ_{CL} and γ_E have the opposite sign, the result is unambiguous because both comparisons favor the same regime. In (a), entry is preferred to both staying out

and CL, so immediate entry must result. In part (d), staying out dominates entry while CL is better than entry, making CL the surplus maximizing regime.

For the remaining cases where γ_E and γ_{CL} have the same sign, there are conflicting effects because one component favors CL while the other favors entry. Part (b) is the case in which entry is less attractive than staying out but more attractive than CL. Entry by the multinational in the last possible period minimizes the losses resulting from the international price spillovers prior to the date at which a compulsory license is imposed, while avoiding the losses that would result in the imposition of a compulsory license during period N_{CL} . The losses from entry prior to T_{CL} shrink to 0 as $D \rightarrow 0$, so that preemptive *entry* maximizes total surplus provided bargaining frictions are small enough that entry can occur arbitrarily close to the deadline for CL. Part (c) is the case where entry is more attractive than staying out, but CL is more attractive than entry in terms of a per period payoff comparison. The question then becomes whether the delay prior to CL is sufficiently short so that it is worth waiting for it.

Recall that in the absence of the threat of CL, the solution to the bargaining problem results in entry by the multinational at the time that maximizes total surplus. We now show that this result also applies when the South can impose a compulsory license.

Lemma 2 *In the alternating offers bargaining game with CL, the solution results in the first acceptable offer for entry being made at the surplus maximizing entry time identified in Proposition 2.*

This result is due to the fact that the proposer at any time i has an interest in choosing the decision that makes joint surplus as large as possible. Consider for example the decision at $N_{CL} - 1$, the last period before a CL would be imposed. The best acceptable offer by the multinational makes the South indifferent between accepting and waiting to impose a compulsory license at N_{CL} , which yields the multinational a payoff of

$$\left[v^E (1 - e^{-rD(N-N_{CL}+1)}) - w_{CL}^S (e^{-rD} - e^{-rD(N-N_{CL}+1)}) \right] / r$$

If the multinational does not make an offer, its payoff is the return to waiting until a compulsory license is issued in the next period,

$$[\hat{\pi}^N(1 - e^{-rD}) + w_{CL}^M(e^{-rD} - e^{-rD(N-N_{CL}+1)})]/r$$

Entry is preferred to waiting for a compulsory license at $N_{CL} - 1$ if

$$\gamma_E(1 - e^{-rD}) - \gamma_{CL}(e^{-rD} - e^{-rD(N-N_{CL}+1)}) \geq 0 \quad (12)$$

It can be seen from (10) that this condition will be satisfied iff $V_0^E(N_{CL}-1) - V_0^{CL} \geq 0$, so an offer is made at $N_{CL} - 1$ iff entry at $N_{CL}-1$ yields a joint payoff that is at least as high as that obtained by waiting for a CL. The Lemma then follows using induction arguments.

Table 1 summarizes how the threat of CL affects the equilibrium of the bargaining game.

Table 1: How the threat of CL affects the equilibrium

	No threat of CL	CL is a credible threat	
		$\gamma_{CL} < 0$	$\gamma_{CL} > 0$
$\gamma_E \geq 0$	enter at 0	enter at 0	CL at T_{CL} if $T_{CL} < \hat{T}$, otherwise immediate entry
$\gamma_E < 0$	no entry	entry at $T_{CL}-1$ if (10) holds CL at T_{CL} otherwise	CL at T_{CL}

There are three possible reasons why a compulsory license can be issued in equilibrium. First, it can be issued when both CL and staying out dominate entry (i.e. $\gamma_{CL} > 0$ and $\gamma_E < 0$). In this case CL provides the South with access to a product that it would not have had otherwise. Second, CL can arise when it is preferred to entry ($\gamma_{CL} > 0$) but entry is preferred to staying out ($\gamma_E \geq 0$) and the delay period preceding CL is not too long. In this case, CL delays access to the product for the South because joint surplus is higher if the multinational stays out and reaps

monopoly profits in the North market until the compulsory license is imposed. The third and final scenario where CL can arise is one where entry is preferred to CL ($\gamma_{CL} < 0$), staying out is preferred to entry ($\gamma_E < 0$), and bargaining frictions are sufficiently large. In this case as well, the threat of CL ensures that the South obtains access to the patented product that it would not have had otherwise, but the product is not provided by the most efficient means. Once the option of staying out is off the table, total surplus would be higher if the product were provided via entry as opposed to CL. However, bargaining frictions prevent multinational from making an acceptable offer to the South prior to the deadline for CL.

We now turn to the question of how the threat of CL affects the respective payoffs of the two parties.

4.2 Equilibrium Payoffs with $\gamma_{CL} < 0$

We begin with the case in which CL yields a lower joint payoff than entry, so that both parties have an interest in avoiding the imposition of a compulsory license. The length of the delay required before the South can issue a CL plays a critical role in determining the impact of the CL on the payoffs to the respective parties. Therefore, it is useful to define $\mu(T_{CL}) = \left(\frac{e^{-rT_{CL}} - e^{-rT}}{1 - e^{-rT}} \right)$ as a measure of the relative importance of payoffs received after the time at which a CL can be issued. If a party receives a constant payoff stream in the time interval $[0, T]$, then $\mu(T_{CL})$ is the share of the present value of that stream that is received after T_{CL} .

With this definition of $\mu(T_{CL})$, we can state:

Proposition 3 *In the bargaining game with a CL deadline of T_{CL} and $\gamma_{CL} < 0$, the equilibrium payoffs have the following properties:*

(a) *If $\gamma_E \geq 0$, entry occurs in the first period. The average payoff to the South in the limiting case as $D \rightarrow 0$ is*

$$\left(\frac{\gamma_E}{2} \right) (1 - \mu(T_{CL})) + w_{CL}^S \mu(T_{CL}) > \frac{\gamma_E}{2}$$

and the average payoff to the multinational is

$$\hat{\pi}^N + \frac{\gamma_E}{2} - (w_{CL}^S - \frac{\gamma_E}{2})\mu(T_{CL}) < \hat{\pi}^N + \frac{\gamma_E}{2}.$$

(b) If $\gamma_E < 0$, and (10) holds, preemptive entry occurs at T_{CL} . The average payoff to the South in the limiting case as $D \rightarrow 0$ is

$$w_{CL}^S \mu(T_{CL}) > 0$$

and the average payoff to the multinational is

$$\hat{\pi}^N + (\gamma_E - w_{CL}^S) \mu(T_{CL}) < \hat{\pi}^N$$

If $\gamma_E < 0$ and (10) is not satisfied, entry does not occur and each party receives the present value of its return from a compulsory license in period N_{CL} .

If $\gamma_E \geq 0$, the proposer has an incentive to make an offer in each period. The only difference between this bargaining problem and the one without CL is the terminal condition, which gives the South's payoff under a compulsory license at T_{CL} . The equilibrium payoff to the South with the threat of CL is a weighted average of its average payoff in the bargaining game without this threat, $\frac{\gamma_E}{2}$, and its average payoff that the South would receive if it were to impose a compulsory license, w_{CL}^S , where the weight placed on the payoff under the compulsory license is the effective fraction of the life of the patent that is captured under a compulsory license, $\mu(T_{CL})$. Since $\mu(T_{CL})$ is decreasing in T_{CL} , the South prefers a shorter deadline for the imposition of a license. The compulsory license has no effect on the timing of entry when $\gamma_E \geq 0$ and $\gamma_{CL} < 0$, but it redistributes surplus from the multinational to the South.

If $\gamma_E < 0$, entry occurs just prior to the time at which the compulsory license would be imposed if bargaining frictions are not too large. The average payoff to the South is its average payoff in the event that a compulsory license is imposed, weighted by the effective fraction of the life of the patent that is covered by the license. Since the South receives a payoff of zero in the absence of the threat of CL, the South benefits from the threat of CL in this case as well. The South also benefits in the

case where D is sufficiently large that preemptive entry is not profitable, because a compulsory license provides a positive payoff to the South under Assumption 1. The difference from the previous case is that in addition to redistributing surplus, the threat of CL also changes the entry decision when $\gamma_E < 0$ and bargaining frictions are not too large.

To show the effect of the deadline for the case of $\gamma_E > 0 > \gamma_{CL}$, we provide a numerical example that is illustrated in Figure 1. The horizontal dotted line in Figure 1 at $\frac{\gamma_E}{2} = 0.14$ represents the payoff to each party when there is no threat of CL. Parameter values are chosen such that the multinational (labeled M in Figure 1) produces a higher quality product than the licensee, but the payoff to the South (labeled S) under a compulsory license exceeds $\frac{\gamma_E}{2}$ due to the South's ability to price the product at marginal cost and pay a relatively low royalty to the multinational.¹⁶ The vertical intercepts of the payoff loci for the respective parties in Figure 1 represent their respective payoffs under a compulsory license, since $T_{CL} = 0$ corresponds to immediate use of CL. In this example, the multinational receives a payoff that is less than its outside option payoff of $\hat{\pi}^N$ when T_{CL} is sufficiently low. The South is able to capture more than the surplus from entry in this case because it must be compensated for its threat to impose a CL. As T_{CL} increases, the value of CL as a threat point decreases and surplus is redistributed from the South toward the multinational. The payoff to each party converges to $\frac{\gamma_E}{2}$ as T_{CL} approaches $T = 20$, the duration of the patent.

It should be noted that the payoff to the multinational is independent of its payoff in the event that a compulsory license is issued, w_{CL}^M , as long as it continues to satisfy $\gamma_{CL} < 0$. This is due to the assumption that for all $D > 0$, the South is only

¹⁶We assume $q = 1$, $n = 2$ and $m = 3.5$. These parameter values reflect a Northern market that has a larger scale (n) and a larger choke price (m) than the South, and result in a profit maximizing price of $\frac{7}{4}$ in the North and $\frac{1}{2}$ in the South. With a spillover parameter of $k = 2.5$, we obtain a price $\hat{p} = .614$ that maximizes surplus and a gain from entry of $\gamma_E = .285$. While the Southern market is less profitable than the Northern market, the pricing spillover is sufficiently small that entry yields higher profits than staying out. We assume that the product has a useful life of $T = 20$, and that the discount factor $r = .05$. In the event of a compulsory license, it is assumed that the quality of the licensee's product is $q_{CL} = .8$ and that the multinational receives a royalty of $R = .025$, which is 10% of its monopoly profit. These assumptions give the South a payoff of $w_{CL}^S = .375$, which exceeds the payoff received under bargaining without the threat of CL.

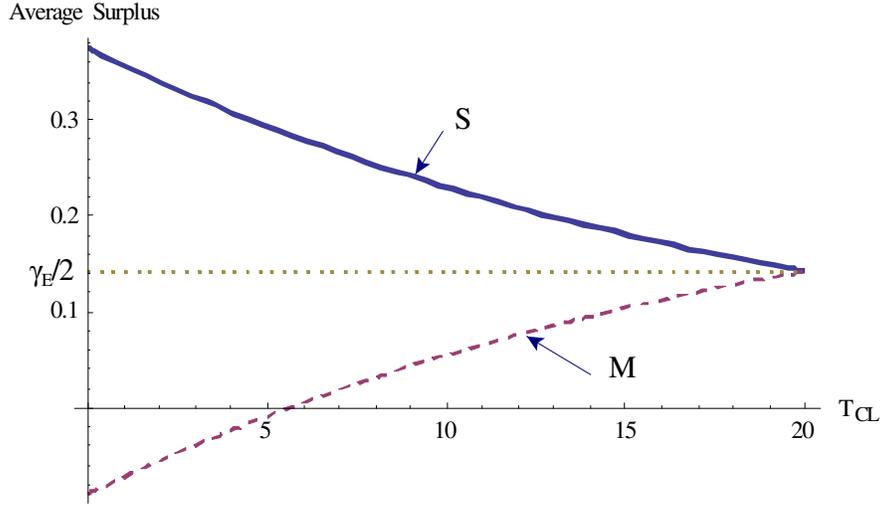


Figure 1: Division of Surplus when $\gamma_{CL} < 0 < \gamma_E$

able to impose the compulsory license at the first period after T_{CL} in which it is the proposer. The multinational always has the chance to make an offer in the last period before a compulsory license would be imposed, and at that point the multinational would make an offer that makes the South indifferent between accepting the offer and waiting for the compulsory license.¹⁷

4.3 Equilibrium Payoffs with $\gamma_{CL} \geq 0$

We now turn to the case in which the issuance of a compulsory license increases the flow surplus relative to entry. When CL has the potential to increase total surplus, we obtain a richer set of possible impacts on the average payoffs of the two parties.

¹⁷If we were to make the alternative assumption that the South makes the last offer before a compulsory license is imposed, it would choose an offer that makes the multinational indifferent between accepting the offer and receiving its payoff under the license. In that case, the multinational's payoff would depend on w_{CL}^M . But the conclusion that the South gains from the threat of CL would hold in this case as well.

Indeed, we show below that when $\gamma_{CL} \geq 0$ the threat of CL can benefit the South at the expense of the multinational, benefit both parties, or somewhat paradoxically, benefit the multinational at the expense of the South.

Proposition 4 *In the bargaining game with $\gamma_{CL} \geq 0$, the payoffs for the parties in the limit of the alternating offers bargaining game have the following properties:*

(a) *If $\gamma_E < 0$ or $\gamma_E \geq 0$ and $T_{CL} < \hat{T}$, the South issues a compulsory license at T_{CL} . The average payoff to the South is $w_{CL}^S \mu(T_{CL})$ and the average payoff to the multinational is $\hat{\pi}^N (1 - \mu(T_{CL})) + w_{CL}^M \mu(T_{CL})$.*

(b) *If $\gamma_E \geq 0$ and $T_{CL} > \hat{T}$, entry occurs immediately. The average payoff to the South is*

$$\frac{\gamma_E(1 - e^{-r\tau})}{2(1 - e^{-rT})} + w_{CL}^S \mu(T_{CL}).$$

and the average payoff to the multinational is

$$\hat{\pi}^N (1 - \mu(T_{CL})) + \frac{\gamma_E(1 - e^{-r\tau})}{2(1 - e^{-rT})} + w_{CL}^M \mu(T_{CL})$$

where $\tau \in (\hat{T}, T_{CL})$ satisfies $\gamma_E(e^{-r\tau} - e^{-rT_{CL}}) - \gamma_{CL}(e^{-rT_{CL}} - e^{-rT}) = 0$.

Part (a) refers to cases in which the equilibrium results in the issuance of a compulsory license at T_{CL} . If $\gamma_E < 0$, the CL must make the South better off since it receives no payoff in its absence. The average payoff to the multinational is a weighted average of its payoff from the Northern market prior to the CL and its payoff under the CL. The multinational benefits from the CL iff

$$\pi_{CL} + R > \hat{\pi}^N$$

We thus have the possibility that the CL leads to a Pareto improvement in this case.

If $\gamma_E \geq 0$ and $T_{CL} < \hat{T}$, the imposition of a compulsory license in equilibrium raises the payoff to the South above what it would obtain from multinational entry as long as $\frac{\gamma_E}{2} \leq \frac{w_{CL}^S(e^{-rT_{CL}} - e^{-rT})}{(1 - e^{-rT})}$. As $T_{CL} \rightarrow 0$, this condition must hold as a result of Assumption 1. Note however that the payoff to a CL is declining in T_{CL} for

$T_{CL} \in [0, \hat{T}]$ because of the increased delay in obtaining the product as T_{CL} increases. Therefore, the South benefits from a CL for all cases in (a) for $\gamma_E \geq 0$ if it benefits when $T_{CL} = \hat{T}$. Since \hat{T} is defined by the condition that $\gamma_E(1 - e^{-r\hat{T}})/r = \gamma_{CL}(e^{-r\hat{T}} - e^{-rT})/r$, the South is at least as well off for $T_{CL} \in [0, \hat{T}]$ if

$$w_{CL}^S \geq \frac{\gamma_E + \gamma_{CL}}{2} = \frac{v_{CL} - \hat{\pi}^N}{2} \quad (13)$$

Condition (13) shows that when $\gamma_{CL} > 0$ and $\gamma_E \geq 0$, the fact that the threat of CL is credible is *not* sufficient to ensure that the South benefits from it. Since the joint surplus from a CL is exactly equal to that from entry at \hat{T} , the South's share of the surplus from a CL must be at least as large as its share of the surplus from entry (i.e. 1/2) in order for it to benefit from the CL.

Part (b) considers the case where $\gamma_E \geq 0$ and $T_{CL} \in [\hat{T}, T]$, so that the deadline for imposing the compulsory license is sufficiently far off that the joint payoff is maximized by immediate entry. However, the fact that the CL yields higher per period surplus than entry means that there will exist some calendar time $\tau(T_{CL}) < T_{CL}$ at which the surplus from entry is exactly equal to that obtained by waiting for a CL. This results in an important change in the bargaining game, since no acceptable offers would be made at any $t > \tau$ because the surplus is larger if the parties wait for the CL. Thus, the relevant threat point for the bargaining game is the payoff to the proposer in the last period before time τ . The proposer in the last period before τ will receive a payoff equal to the difference between the payoff from entry and the payoff earned by the responder if it waits for the issuance of a CL in period N_{CL} . This last mover advantage disappears in the limit as $D \rightarrow 0$, because the calendar time at which the last offer is made will converge to τ . In the limiting case, the identity of the last mover does not matter because τ is defined to be the period at which the total surplus from entry exactly equals the total surplus from waiting for a CL. Each party will receive the value of its payoff under a CL, discounted to τ , if entry occurs at τ .

A comparison of the payoffs in (a) and (b) illustrates that since $\tau(\hat{T}) = 0$, the payoffs will be continuous in T_{CL} at $T_{CL} = \hat{T}$. Differentiating the South's payoff

with respect to T_{CL} (taking into account the dependence of τ on T_{CL}), it can be shown that the average payoff to the South is decreasing in T_{CL} for $T_{CL} > \hat{T}$ iff (13) holds. When (13) is satisfied, the payoff to the South from a compulsory license is sufficiently high that it serves as a valuable threat point for the South, so delaying the deadline for CL harms the South's interests. In this case the payoff to the South will be monotonically decreasing on $[0, T]$. If (13) does not hold, the threat of CL is actually beneficial to the multinational, so the South benefits if the deadline for a compulsory license is delayed. Since the payoff to the South is less than $\frac{\gamma}{2}$ at \hat{T} and equals $\frac{\gamma}{2}$ at T , the South is worse off from the threat of a CL on $[\hat{T}, T)$.

These observations yield the following relationship between the deadline and the value of CL for the South:

Corollary 1 *In the case where $\gamma_E \geq 0$ and $\gamma_{CL} > 0$, the following hold:*

(i) *If inequality (13) holds, the payoff to the South is non-increasing in T_{CL} and the threat of a CL cannot decrease the welfare of the South. The South is everywhere better off if the inequality is strict.*

(ii) *If (13) fails, the payoff to the South is decreasing in T_{CL} for $T_{CL} < \hat{T}$ and increasing in T_{CL} for $T_{CL} > \hat{T}$. The South is strictly worse off due to the threat of CL for all $T_{CL} \in [\hat{T}, T)$.*

We conclude by providing two numerical examples that illustrate each of the cases in the Corollary. For each example, the payoffs under entry are identical to those in Figure 1 but the CL payoffs are chosen such that $\gamma_{CL} > 0$. Figure 2 illustrates the equilibrium payoffs to the parties as given by Proposition 4 for a case that is consistent with part (i) of the corollary. Here, the South captures most of the benefits of CL since the parameter values for this example imply that (i) the South pays a royalty to the multinational that is only 10% of the profits that the multinational would have earned under entry; (ii) the licensee's product is of the same quality as that of the multinational; and (iii) CL eliminates the price spillover between markets.¹⁸

¹⁸Specifically, we assume that $q = q_{CL} = 1$ and $R = 0.025$. With these assumptions, $\gamma_{CL} = 0.215$ and $w_{CL}^S = 0.475 > (\gamma_E + \gamma_{CL})/2 = 0.25$ as required for (13) to be satisfied.

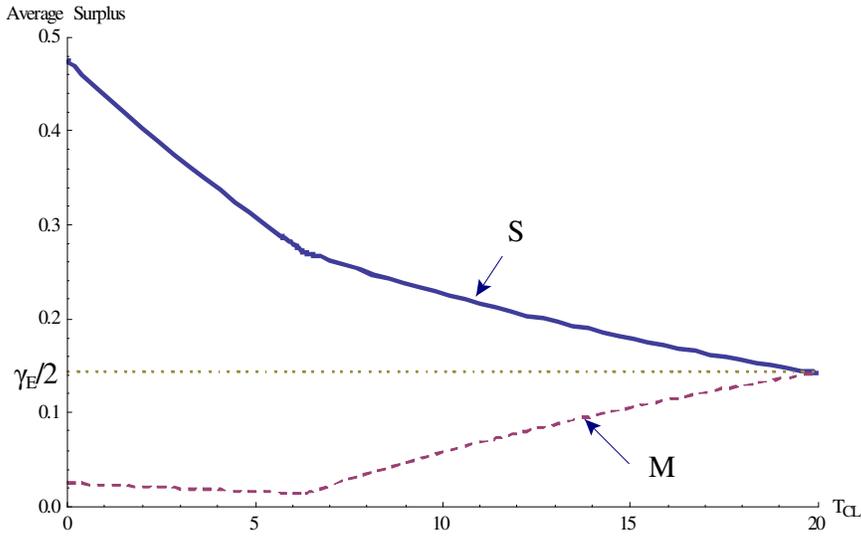


Figure 2: Division of surplus when $\gamma_E, \gamma_{CL} > 0$ and (13) holds

The vertical intercepts in Figure 2 reflect the average payoffs to the respective parties under a compulsory license, and show that the South captures virtually all of the surplus under the CL in this example. For $T_{CL} < \hat{T} = 6.34$, a compulsory license is the equilibrium outcome of the bargaining game and each party receives the present value of the compulsory license payoff starting at time \hat{T} . The payoff to both parties is decreasing in T_{CL} in this region, because delay in implementing the compulsory license reduces the period over which the license operates. For $T_{CL} > \hat{T}$, the delay for a compulsory license is sufficiently long that immediate entry is preferred. The sum of payoffs to the two parties is constant in this interval, so the effect of a change in T_{CL} is to redistribute surplus between the parties. The payoff to the South is decreasing in T_{CL} in this region, because delay weakens the use of the threat of CL for the South. The threat of CL benefits the South for all $T_{CL} < T$ in this case.

The second example illustrates part (ii) of the Lemma, with the distribution of the surplus under CL favoring the multinational. The parameter values in this example

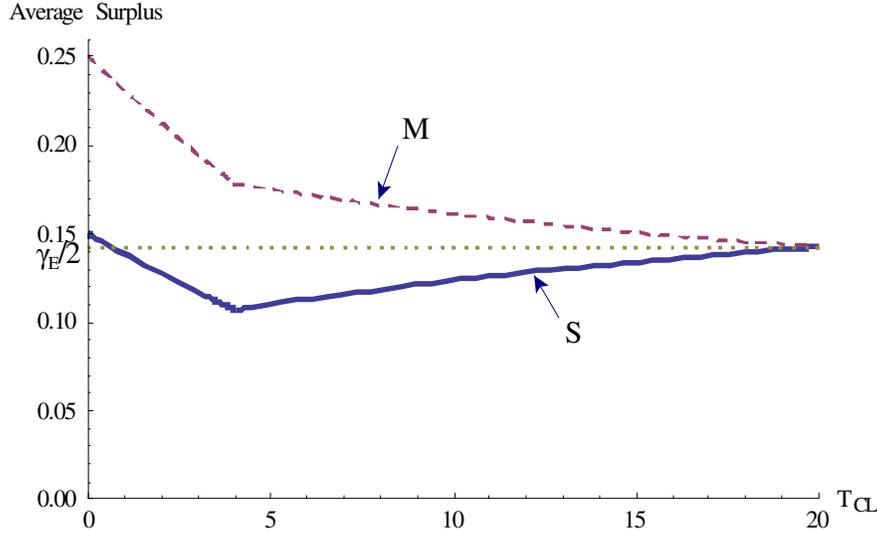


Figure 3: Division of Surplus with $\gamma_E, \gamma_{CL} > 0$ and (13) does not hold

differ in that the quality of the licensee's product is less than that of the multinational and the required royalty payment is equal to the profit the multinational would have earned if it entered the market and set the monopoly price. Both of these factors, i.e. a lower quality product and a higher royalty payment under CL, reduce the average CL payoff of the South compared with the previous case.¹⁹ The average payoffs to the parties under a compulsory license are shown by the vertical intercepts in Figure 3, which illustrate that the multinational receives a higher absolute payoff under CL than the South. Note however that CL represents a credible threat for the South because its average payoff under CL exceeds that which it obtains by continuing to bargain: $w_{CL}^S = 0.15 > \frac{\gamma_E}{2} = 0.14$.

¹⁹In this case $q_{CL} = 0.8$ and $R = 0.25$. All other parameters remain the same as in the previous example. These parameter values result in $\gamma_{CL} = 0.1$. The payoff to the South under CL is $w_{CL}^S = 0.15 < \frac{\gamma_E + \gamma_{CL}}{2} = 0.2$, so (13) does not hold.

A CL is issued for $T_{CL} < \hat{T} = 4$. Note that \hat{T} is lower in this case relative to Figure 2, because the lower quality product of the licensee reduces γ_{CL} . For T_{CL} sufficiently close to 0, CL results in a Pareto improvement because both parties receive a payoff exceeding $\gamma_E/2$. The payoff to both parties is decreasing in T_{CL} for $T_{CL} < \hat{T}$, and the payoff to the South declines below that obtained without the threat of CL. For $T_{CL} > \hat{T}$, entry occurs at $t = 0$ and the sum of payoffs to the two parties is a constant. The difference with the previous example is that in this case the payoff to the South increases with T_{CL} . This occurs because the South's surplus is sufficiently small under a compulsory license that the threat of CL actually favors the multinational.

The case where $\gamma_{CL} > 0$ requires that the WTO provides an enforcement mechanism that limits spillovers to the South from sales of the patented product under a compulsory license, and that the South's promise to limit such spillovers is not credible without the external enforcement provided by the WTO (say via its dispute settlement process). We have shown that in such cases, the possibility of CL can *strengthen the bargaining position of the multinational* and hurt the South if the multinational's share of the surplus under a compulsory license is sufficiently large.

4.4 Alternative Assumptions Regarding Permissible Agreements

We conclude our analysis with a brief discussion of how our results would be affected under alternative assumptions regarding the types of agreements that are allowed. The first extension we consider is to allow agreements in which the multinational makes a transfer to the South in return for a promise on its part to not issue a compulsory license. The option of staying out yields a joint payoff of $V^N = \hat{\pi}^N(1 - e^{-rDN})/r$, so that the maximization of joint payoffs involves choosing the largest of $\{\max V^E(i), V^{CL}, V^N\}$. Staying out is dominated by entry for any $i \geq 0$ when $\gamma_E < 0$, which simplifies the choice to $\max\{V^N, V_0^E(0), V^{CL}\}$. Parts (a) and (c) of Proposition 2 are unaffected by this extension, since V^{CL} is dominated by $V_0^E(0)$ in those cases. If $\gamma_E < 0$, staying out dominates entry so the choice is between staying

out and CL. The introduction of the option to stay out modifies parts (b) and (d) of Proposition 2 such that there will be no entry if $\gamma_E < 0$ and $\gamma_E + \gamma_{CL} = v_{CL} - \hat{\pi}^N < 0$ and a compulsory license will be issued if $\gamma_E < 0$ and $\gamma_E + \gamma_{CL} > 0$.

The main effect of allowing the multinational to offer a transfer to prevent the issuance of a compulsory license is that preemptive entry does not arise in equilibrium. A transfer to the South to avoid CL is a less costly way for the multinational to avoid CL relative to preemptive entry, so the multinational would choose that option if it is available. The cases with $\gamma_E > 0$ are unaffected, so the payoffs identified in Propositions 3 and 4 for the case with $\gamma_E \geq 0$ continue to apply.

A second extension is to consider the case where no transfers of any type are allowed in the bargaining game. In this case the two parties bargain over price if the multinational enters. The prices from firm entry that are not Pareto dominated are $p \in [0, p_{\max}]$, where $p = 0$ reflects marginal cost pricing for the product and $p_{\max} = \arg \max \pi^G(p, q)$ maximizes the multinational's global profits under entry. For the payoff functions defined in (1) and (2), we obtain a strictly concave payoff frontier for the bargaining game in the absence of transfers.

In the absence of CL, it can be shown that the multinational will enter as long as its maximum possible global profit from entry exceeds the profit from staying out, $\pi^G(p_{\max}, q) \geq \hat{\pi}^N$. This entry condition is more stringent than in the case with transfers because the South is unable to subsidize entry by making a transfer when the joint surplus is positive. It can also be shown that preemptive entry arises in the limiting case as $D \rightarrow 0$ if $\pi^G(p_{\max}, q) < \hat{\pi}^N$ and the joint payoffs under CL lie inside the payoff frontier under entry. This result is similar to that obtained in Proposition 2b, where the multinational enters at time $N_{CL} - 1$ if the losses from entry are smaller than those under CL and the bargaining friction D is not too large.

The above results illustrate two ways in which bargaining frictions affect the possibility of preemptive entry. The inability to use a lump sum transfer to prevent the issuance of a compulsory license, which represents a form of bargaining friction, is necessary for preemptive entry to arise. However, bargaining frictions in the form of delay between offers (i.e. $D > 0$) make it less likely that preemptive entry occurs because the losses resulting from preemptive entry prior to the CL deadline must be

incurred for a longer period of time.

5 Conclusion

During the last decade or so, developing countries have increasingly started to turn to CL as a tool for improving consumer access to patented foreign medicines. The available evidence indicates that in almost all cases of CL that have been observed since the ratification of TRIPS, price negotiations between multinational firms selling patented drugs and developing countries have tended to precede the actual issuance of a compulsory license. This observation lies at the heart of the model developed in this paper that considers bargaining between a multinational and a developing country that wishes to gain access to its patented product at as low a price as possible.

The model compares two scenarios: one where the two parties engage in bilateral price bargaining with no possibility of CL and another where the developing country has the authority to issue a compulsory license if negotiations between the two parties do not succeed by a certain time period. Each of the requirements specified in Article 31 of TRIPS that sanctions CL plays an important role in our model. While the “adequate remuneration” rule simply ensures that CL compensates the multinational to some degree, the effect of the other two rules is more subtle. For example, the requirement that CL can only be issued if the patent is not worked locally and price negotiations do not conclude successfully by a certain time period implies that, if it so chooses, the multinational can preempt the use of CL by the developing country government. Our model provides conditions under which the multinational finds it optimal to preempt CL as well as when it does not. In the former case, the credible threat of CL weakens its bargaining position and lowers its share of the total surplus.

Our model clarifies that the possibility of CL need not necessarily lead to an outcome where one party’s gains come at the expense of the other. The logic for this is as follows. Since the government issuing a compulsory license has to ensure that the patented product is sold primarily in the local market, the possibility that international pricing spillovers undermine the multinational’s profits in its other markets

can be greatly reduced or eliminated altogether under CL. Similarly, the fact that the multinational does not control pricing and production under CL implies that the price at which the good is sold in a developing country issuing a compulsory license is less likely to run afoul of external reference pricing policies of other countries. Consequently, the low prices of drugs produced under CL are likely to have little or no bearing on high prices in rich countries.

It is clear that the enforcement of the “local consumption requirement” of the CL contract is quite valuable to the multinational. Our model shows that the proper enforcement of this requirement has the potential to expand the joint payoff shared between the multinational and the developing country. The implication of this result is that for the use of CL by developing countries to be more palatable to foreign patent-holders, such countries need to ensure that there is no leakage of products produced under CL to markets in rest of the world.

Although our analysis has focused on the case of compulsory licensing, our model would also apply to other bargaining problems where the payoff available to the two parties may increase at a prespecified deadline. Our results highlight the fact that in such situations, as the deadline approaches, the attractiveness of making an offer declines relative to waiting for the deadline. As a result, the ability to delay agreement until the deadline plays an important role in determining the payoffs to the parties.

Appendix

Proof of Lemma 1

Suppose that $m > 2k$, so that the no arbitrage constraint binds for $p^S \in [0, q]$. In this case $v(p^S)$ is strictly concave in p^S on $[0, q]$ by (1) and (2). For $m > \frac{2nk^2}{nk-1}$, $v(p^S)$ is strictly increasing on $[0, q]$. Since $v(q) = \pi^G(q)k$ and $kp^S < \hat{p}^N$ in this case, we have $v_E < \hat{\pi}^N$. For $m \leq \frac{2nk^2}{nk-1}$, $v(p^S)$ achieves a local maximum at

$$\tilde{p} = \frac{kmnq}{2nk^2 + m} \leq q,$$

yielding a joint payoff of

$$v_E = \frac{q}{2} \left(\frac{2nk^2 + m + n^2k^2m}{2nk^2 + m} \right)$$

Comparing this payoff with that obtained by selling only in the Northern market at \hat{p}^N , $\frac{mq}{4}$, yields the condition $m < m^* \equiv \frac{1 + \sqrt{1 + (2nk)^2}}{n}$ for selling in the Southern market.

For $m < 2k$, $v(p^S)$ is strictly concave in p^S on $[0, \frac{mq}{2k}]$ and decreasing at $p^S = \frac{mq}{2k}$. The joint payoff is maximized by setting $p^S = \tilde{p}$.

Proof of Proposition 1: Letting W_i^S be the payoff to S at a subgame starting in period i at which S is the proposer and $V_i^E = v_E (1 - e^{-rD(N-i)}) / r$ the current value of entry at i , we have

$$W_i^S = \max \left\{ V_i^E - \hat{\pi}^N (1 - e^{-rD}) / r - e^{-rD} W_{i+1}^M, e^{-rD} W_{i+1}^S \right\} \quad (14)$$

The first term in brackets is the maximum return to S from making an acceptable offer to M , which is the difference between the joint payoff from entry and the payoff that M could earn by rejecting the offer and waiting to be proposer in the next period, $\hat{\pi}^N (1 - e^{-rD}) - e^{-rD} W_{i+1}^M$. The second term in brackets is the return to S from not making an offer. Since S earns nothing if M does not enter, the value of not making an offer is simply the discounted value of the payoff in the subgame beginning at $i + 1$. The payoff to M in a period j in which it is the proposer is

$$W_j^M = \max [V_j^E - e^{-rD} W_{j+1}^S, \hat{\pi}^N (1 - e^{-rD}) / r + e^{-rD} W_{j+1}^M] \quad (15)$$

Since $W_N^M = W_N^S = V_N^E = 0$, an acceptable offer will be made in period $N - 1$ iff $\gamma_E \geq 0$. From (14) and (15), an acceptable offer will be made in period $i < N$ if

$$\gamma_E (1 - e^{-rD}) \geq r e^{-rD} (W_{i+1}^S + W_{i+1}^M - V_{i+1}^E) \geq 0 \quad (16)$$

This condition is never satisfied for $\gamma_E < 0$, so M will not enter. If an offer is made in period $i + 1$, the right side equals 0 and an offer will be made in period i if $\gamma_E \geq 0$.

It then follows by induction that an acceptable offer will be made at $i = 0$ when $\gamma_E \geq 0$.

To solve for S 's payoff when $\gamma_E \geq 0$, consider a period $i < N$ at which S is the proposer. Since S would make an acceptable offer at i and M would make an acceptable offer at $i + 1$, we can substitute from (15) into (14)

$$W_i^S = \frac{\gamma_E(1 - e^{-rD})}{r} + e^{-2rD}W_{i+2}^S. \quad (17)$$

Consider the case in which S moves first and M moves last. The patent expires at the beginning of period N , so $W_N^S = 0$. With this terminal condition, (17) yields $W_0^S = \frac{\gamma_E(1 - e^{-rD})}{r} \sum_{i=0}^{N/2-1} e^{-2rD(i-1)} = \frac{\gamma_E(1 - e^{-rD})}{r(1 + e^{-rD})}$. Multiplying by $\frac{r}{(1 - e^{-rT})}$ yields the average payoff of $\frac{\gamma_E}{1 + e^{-rD}}$ for S , which gives S a first mover advantage for $D > 0$. If M moves first and S moves last, the payoff to S is $\frac{e^{-rD}\gamma_E(1 - e^{-rD})}{r} \sum_{i=1}^{N/2} e^{-rD2(i-1)}$, yielding an average payoff of $\frac{e^{-rD}\gamma_E}{1 + e^{-rD}}$. In either case the S payoff converges to $\frac{\gamma_E}{2}$ as $D \rightarrow 0$. A similar result is obtained if one of the parties moves both first and last.

Proof of Proposition 2:

Entering at i dominates waiting for a CL if

$$r(V_0^E(i) - V_0^{CL}) = \gamma_E(e^{-rDi} - e^{-rN_{CL}D}) - \gamma_{CL}(e^{-rN_{CL}D} - e^{-rT}) \geq 0 \quad (18)$$

If $\gamma_E \geq 0$, entering at $i = 0$ will dominate entering at any $i > 0$ so the comparison is between $V_0^E(0)$ and V_0^{CL} . If $\gamma_{CL} < 0$, (18) must be satisfied at $i = 0$. If $\gamma_{CL} > 0$, there will exist some \hat{T} such that (18) will be satisfied at $i = 0$ only if $DN_{CL} \geq \hat{T}$. This establishes (a) and (c).

For $\gamma_E < 0$, entering at $i = N_{CL} - 1$ dominates entering at any $i < N_{CL}$. Waiting for the CL must be preferred to entry at $N_{CL} - 1$ if $\gamma_{CL} \geq 0$, because (18) must be negative. For $\gamma_{CL} < 0$, entry at $N_{CL} - 1$ is preferred to waiting for the CL if (10) is satisfied, which must hold for D sufficiently small since $\lim_{D \rightarrow 0, N_{CL}D \rightarrow T_{CL}} V_0^E(N_{CL} - 1) - V_0^{CL} = -\gamma_{CL}(e^{-rT_{CL}} - e^{-rT})/r$.

Proof of Lemma 2:

(a) $\gamma_E \geq 0$, $\gamma_{CL} < 0$: Condition (12) is satisfied in this case, so an acceptable

offer would be made at $N_{CL} - 1$. If an offer is made at $i + 1 < N_{CL} - 1$, the right hand side of (16) is 0 and the proposer will make an acceptable offer at i . It then follows by induction that an acceptable offer will be made at $i = 0$.

(b) $\gamma_E < 0, \gamma_{CL} < 0$: If condition (12) fails, the proposer will not make an acceptable offer at $N_{CL} - 1$. Assuming no offer at $i + 1$, the right hand side of (16) will be positive and no offer will be made at i . It follows by induction that no offers will be made and the CL is imposed at N_{CL} . If (12) is satisfied, an offer will be made at $N_{CL} - 1$. However, no offer will be made at $N_{CL} - 2$ because the right hand side of (16) is non-negative. It then follows by the previous induction argument that no offer is made at $i < N_{CL} - 1$, so entry occurs at $N_{CL} - 1$. This case must apply as $D \rightarrow 0$ by the argument in Proposition 2b.

(c) $\gamma_E \geq 0, \gamma_{CL} \geq 0$: For this case, it is useful to define the function

$$\Lambda(i, DN_{CL}, D) = [(1 - e^{-rD(N_{CL}-i)})\gamma_E - e^{rDi}(e^{-rN_{CL}D} - e^{-rT})\gamma_{CL}] / r, \quad (19)$$

which is the current value of the difference between the value of entering at period i and waiting until period N_{CL} for a compulsory license. $\Lambda(i, DN_{CL}, D)$ will be decreasing in i in this case, with $\Lambda(DN_{CL}, DN_{CL}, D) < 0$.

Suppose no acceptable offer has been made in for any period with index greater than i , so that $W_{i_0+1}^S + W_{i_0+1}^M = e^{rDi}(e^{-rN_{CL}D} - e^{-rT})v_{CL}$. Using (16), the proposer in period i will make an acceptable offer iff $\Lambda(i, DN_{CL}, D) \geq 0$. If an acceptable offer is made in period i , then we can use the same induction argument as in (a) to show that an acceptable offer will be made for all periods $\{0, \dots, i\}$. We then have two possibilities. If there exists a calendar time $\tau \in [0, DN_{CL})$ satisfying $\Lambda(\tau/D, DN_{CL}, D) = 0$, then acceptable offers will be made for all periods $i < \tau/D$ and M will enter at time 0. If $\Lambda(0, DN_{CL}, D) < 0$, then no proposer will make an acceptable offer and the equilibrium outcome will be a CL . Since $\Lambda(0, DN_{CL}, D)$ is increasing in DN_{CL} and $\Lambda(0, \hat{T}, D) = 0$, we have $\Lambda(0, DN_{CL}, D) < 0$ iff $DN_{CL} < \hat{T}$. This establishes (c).

(d) $\gamma_E < 0, \gamma_{CL} \geq 0$: Since (12) fails, the same induction argument as in (b) yields no acceptable offers for $i < N_{CL}$.

Proof of Propositions 3:

(a) If $\gamma_E \geq 0$, then M enters at $i = 0$. If the bargaining game reaches period N_{CL} then S will grant a compulsory license and receive a payoff of $W_{CL}^S = w_{CL}^S(1 - e^{-r(T-DN_{CL})})/r$. We know from Lemma 2 that a proposer will be willing to make an acceptable offer for each period $i < N_{CL}$, so the payoff to S in a period in which S proposes will satisfy (17) with the endpoint $W_{N_{CL}}^S = W_{CL}^S$. If N_{CL} is an even number, S moves first in period 0 and gets to make $\frac{N_{CL}}{2}$ offers before the CL deadline. The payoff to S will be $\frac{\gamma_E}{r} \left(\frac{1-e^{-rDN_{CL}}}{1+e^{rD}} \right) + \frac{w_{CL}^S(e^{-rDN_{CL}}-e^{-rT})}{r}$. Multiplying by $\frac{r}{(1-e^{-rT})}$ gives the average payoff of $\frac{\gamma_E(1-e^{-rDN_{CL}})}{(1-e^{-rT})(1+e^{rD})} + \frac{w_{CL}^S(e^{-rDN_{CL}}-e^{-rT})}{(1-e^{-rT})}$. The payoff to M is $W_0^M = \tilde{V}_0^E - W_0^S$, so the average payoff is $\hat{\pi}^N + \frac{\gamma_E e^{-rD}(1-e^{-rDN_{CL}})}{(1+e^{rD})(1-e^{-rT})} + \frac{(\gamma_E - w_{CL}^S)(e^{-rDN_{CL}}-e^{-rT})}{(1-e^{-rT})}$. Taking the limit as $D \rightarrow 0$ yields the limiting average payoffs for the respective parties in the Proposition. As in the proof of Proposition 1, the same limiting payoff is obtained in the case where N_{CL} is an odd number and M makes the first offer.

(b) If $\gamma_E < 0$ and D is sufficiently small, M enters at $N_{CL} - 1$ with an offer that makes S indifferent between accepting and obtaining a compulsory license. The present value of this payoff to S is $W_0^S = e^{-rDN_{CL}}W_{CL}^S$, which yields an average payoff of $\frac{w_{CL}^S(e^{-rDN_{CL}}-e^{-rT})}{1-e^{-rT}}$. The present value of the total payoff to the two parties is the sum of M 's profit in the North from time 0 to $D(N_{CL} - 1)$, $\frac{\hat{\pi}^N}{r} \left(\frac{1-e^{-rD(N_{CL}-1)}}{r} \right)$, and the payoff to the two parties from time $D(N_{CL} - 1)$ to the expiration of the patent, $\frac{v_E}{r} \left(\frac{e^{-rD(N_{CL}-1)}-e^{-rT}}{r} \right)$. Converting this to an average payoff and subtracting the average payoff to S gives an average payoff to M of $\hat{\pi}^N + (\gamma_E - w_{CL}^S) \left(\frac{e^{-rDN_{CL}}-e^{-r(T-DN_{CL})}}{1-e^{-rT}} \right) + \gamma_E \left(\frac{e^{-rD(N_{CL}-1)}-e^{-rDN_{CL}}}{1-e^{-rT}} \right)$. Taking the limit as $D \rightarrow 0$ yields the result.

Proof of Proposition 4:

(a) It follows from Proposition 2 and Lemma 2 that a CL will be issued if either $\gamma_E < 0$ or if $\gamma_E \geq 0$ and $N_{CL} < \frac{\hat{T}}{D}$. S 's payoff under CL is $W_0^S = e^{-rDN_{CL}}W_{CL}^S$ and M 's payoff is $W_0^M = \frac{\hat{\pi}^N(1-e^{-rDN_{CL}})}{r} + e^{-rDN_{CL}}W_{CL}^M$, where $W_{CL}^i = \frac{w_{CL}^i(1-e^{-r(T-DN_{CL})})}{r}$ for $i = S, M$. The average payoffs as $D \rightarrow 0$ will be $\frac{w_{CL}^S(e^{-rTN_{CL}}-e^{-rT})}{(1-e^{-rT})}$ for S and $\frac{\hat{\pi}^N(1-e^{-rTN_{CL}})+w_{CL}^M(e^{-rTN_{CL}}-e^{-rT})}{(1-e^{-rT})}$ for M .

(b) The proof of Lemma 2(c) showed that if $N_{CL} \geq \frac{\hat{T}}{D}$, then there will exist a

time $\tau \in [0, DN_{CL})$ such that an acceptable offer will be made in period i iff $i \leq \frac{\tau}{D}$. Defining i_τ to be the largest integer less than or equal to $\frac{\tau}{D}$, the proposer in period i_τ would make an offer that makes the respondent indifferent between accepting the offer and waiting for a compulsory license. If M makes the last offer, the payoffs to the respective parties from an offer in period i_τ will be

$$W_{i_\tau}^S = e^{-rD(N_{CL}-i_\tau)}W_{CL}^S; \quad W_{i_\tau}^M = \frac{v_E(1 - e^{-rD(N-i_\tau)})}{r} - e^{-rD(N_{CL}-i_\tau)}W_{CL}^S; \quad (20)$$

The payoff to S from this bargaining game is the payoff to an alternating offers bargaining game in which S is the first mover is $W_0^S = \gamma_E(1 - e^{-rD}) \sum_{i=0}^{i_\tau} e^{-2rDi} + e^{-rDN_{CL}}W_{CL}^S$. As $D \rightarrow 0$, we have $i_\tau D \rightarrow \tau$, $N_{CL}D \rightarrow T_{CL}$ which yields $W_0^S \rightarrow \frac{\gamma_E(1-e^{-r\tau})}{2r} + e^{-rT_{CL}}W_{CL}^S$. The average payoff is then $\frac{\gamma_E(1-e^{-r\tau})}{2(1-e^{-rT})} + \frac{w_{CL}^S(e^{-rT_{CL}}-e^{-rT})}{(1-e^{-rT})}$. The average payoff to M is $v_E - \left(\frac{\gamma_E(1-e^{-r\tau})}{2(1-e^{-rT})} + \frac{w_{CL}^S(e^{-rT_{CL}}-e^{-rT})}{(1-e^{-rT})} \right)$.

If instead S makes the last offer at i_τ , the payoffs are

$$W_{i_\tau}^S = \frac{\gamma_E(1 - e^{-rD(N_{CL}-i_\tau)})}{r} - e^{-rD(N_{CL}-i_\tau)}W_{CL}^M; \quad W_{i_\tau}^M = e^{-rD(N_{CL}-i_\tau)}W_{CL}^M \quad (21)$$

Note that as $D \rightarrow 0$, both (20) and (21) converge to $W_{i_\tau}^j = e^{-r(T_{CL}-\tau)}W_{CL}^j$ for $j = M, S$. For $i_\tau < \frac{\tau}{D}$, the last mover is able to capture the excess of the return from entry over waiting for a compulsory license. However, this last mover advantage disappears as $Di_\tau \rightarrow \tau$.

Proof of Corollary:

Differentiation of the average payoff to S for $T_{CL} > \hat{T}$ yields

$$\frac{r}{1 - e^{-rT}} \left(\frac{\gamma_E e^{-r\tau}}{2} \frac{d\tau}{dT_C} - w_{CL}^S e^{-rT_{CL}} \right) \quad (22)$$

From the definition of τ , $\frac{d\tau}{dT_{CL}} = \frac{(\gamma_E + \gamma_{CL})e^{-rT_{CL}}}{\gamma_E e^{-r\tau}}$. Substituting this result into (22) yields the result that the average payoff is non-decreasing in T_{CL} iff (13) is satisfied.

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