Bargaining over Royalties in the Shadow of Litigation

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Abstract

We model negotiations over patent royalties in the shadow of litigation through a Nash-in-Nash approach, where outside options, triggered in case of disagreement, are derived from a subsequent game of litigation. The outcome of litigation depends both on "hard determinants", such as relative patent strength, and on "soft determinants", such as parties' efficacy in litigation or their (known) preparedness to disrupt negotiations in favor of litigation. Amongst other things, this has implications for the interpretation of observed royalties in empirical analysis.

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1 Introduction

This paper makes two contributions. On a more general level, we consider negotiations between two parties in the shadow of the threat of litigation. Our specific modeling approach may thus inform the literature notably in law and economics. On a more specific level, we consider negotiations over patent royalties. Here, our results may inform also the applied empirical literature on the determinants of such royalties.

Specifically, we take a setting where two parties have secured patents that are, to fix ideas, both essential for a given standard. We characterize the equilibrium (one-way) royalties as the outcome of negotiations in the shadow of possible litigation. For this, we apply a so-called "Nash-in-Nash" bargaining framework. While the Nash bargaining solution specifies how the two parties split the net gains from trade over and above their disagreement payoffs,[1] the latter are in turn determined from the (Nash) equilibrium of a game of litigation. There, we assume that a court (or an arbitration procedure that the two parties have agreed to apply) starts from a "reasonable" royalty rate, as, for instance, determined by relative patent strength, but both parties can engage in costly dispute efforts to "tilt" the litigation outcome to their favor. Even though the parties do not litigate in equilibrium, litigation affects negotiated royalties because it affects the parties' outside options.

Our first set of results concerns the determinants of negotiated royalties. We show that negotiated royalties depend also on bargaining power, which we derive from the two parties' efficacy and attitude towards litigation. Only if the parties' litigation costs are zero or neutral, negotiated royalties solely reflect patent strength. While litigation efficacy affects outside options, the sharing rule of Nash bargaining itself may depend, amongst other things, on the two sides' aggressiveness and their preparedness to turn to litigation. Our second set of results relates to the structure of negotiated royalties. The party with relatively lower litigation costs can tilt indeed both one-way royalties (i.e., the one it receives and the one it pays) to its favor. Ceteris paribus, the same applies to the party that acts relatively more aggressive in negotiations.

We are not the first to apply bargaining concepts and models to the determination

[1] Our extension, where we introduce a non-cooperative model, follows closely Binmore et al. (1986), who extend the framework of Rubinstein (1982) by allowing for time preferences and a risk of breakdown of negotiations and thereby show under which conditions the Nash (1953) bargaining solution can be obtained.

of royalties for patents. The literature has considered the application of bargaining models and concepts both more generally to (hypothetical) licensing agreements and more specifically to agreements concerning standard essential patents. As we do subsequently, overwhelmingly the generalized Nash bargaining solution has been applied.[2] The role of bargaining power in patent licensing negotiations has also been confirmed, and we will return to this literature below.

Our approach combines the Nash bargaining solution with a model of litigation (or dispute).[3] In this way, we derive the outside options from first principles, that is from deeper parameters of the economic situation, e.g., different willingness and ability to litigate. The possibility of litigation (as a threat) has already been evoked in the literature. For instance, Lemley and Shapiro (2007) or Shapiro (2010) explicitly incorporate the possibility of litigation into a bargaining model.

Taking a broader perspective, the role of litigation for the patent system has also been discussed in the literature. Lemley and Shapiro (2005) view patents as a reward for an individual's contribution to economic growth. Nonetheless, encouraging innovation by granting (temporarily) market power also causes social costs. Recently, the hope to claim exclusive rights on a future key technology has led to a flood of patent applications worldwide. For instance, the U.S. Patent and Trademark Office recorded 665.231 patent filings in 2019 (U.S. Patent and Trademark Office, 2019). This hardly manageable number of patent applications has potentially resulted in the granting of many weak or even ultimately unlawful patents. To uncover and invalidate these socially costly patents, litigation has become an inherent part of the patent system.

Our contribution derives the outside options explicitly from primitives and thereby combines, as we will explain, "hard determinants" for the derivation of royalties, notably

[2]Putnam and Tepperman (2004) construct hypothetical examples to guide practitioner negotiations over license agreements. They suggest that the outside option solution concept should only be used in one-off bargaining situations, while the Nash bargaining solution is more suitable in the more common situation when parties interact over an extended period of time. Also Choi and Weinstein (2001) suggest the use of the Nash bargaining solution in the context of royalty rate calculations. Other approaches, like Gilbert (2011), take a more normative picture and compare different bargaining outcomes in a standard-setting context. Finally, as examples of an economic model that uses predictions from the Nash bargaining solution as an input for a greater model in which bilateral licensing agreements are embedded, see, for instance, Kishimoto and Muto (2012) or Shapiro (2010).

[3]The use of bargaining theory and models has also an established tradition in legal studies and, more precisely, in the analysis of legal disputes and their resolution. For an early survey see, for instance, Cooter and Rubinfeld (1989) or the respective sections in the survey by Kennan and Wilson (1993).

a proxy of patent strength, with “softer determinants” that reflect bargaining power.[4]

Organization of the paper. The rest of this paper is organized as follows. Section 2 sets out the bargaining framework and adds gradually more structure to the model, i.e., we move from exogenous to endogenous outside options derived by a subgame of litigation. Subsequently, Section 3 characterizes the equilibrium and works out further factors that explain royalties, apart from pure patent strength. Finally, Section 4 concludes. In Appendix A, we endogenize the sharing rule by introducing a heterogeneous risk of breakdown. In Appendix B, we review the empirical literature documenting different sharing rules, which is one of the presumptions in the following model.

2 The Economic Framework

In this section, we introduce the modeling approach in various steps. We first present the bargaining framework. With a view also on the applied literature, we introduce this framework in a relatively general way. In a second step, we then make more specific assumptions, notably on how the outside options in case of breakdown of negotiations are derived from a game of litigation.

2.1 The Bargaining Framework

We consider two parties that negotiate over one-way royalties for the patent portfolio of the first party. In a straightforward extension, we will subsequently also solve for the outcome when royalties for the second party's portfolio have to be established. Taken together, the two results will then characterize all one-way royalties that a researcher may observe.

The potential agreement is more precisely over a constant royalty rate $0 \leq r \leq 1$ that applies to sales of party 2 and is thus paid by party 2 to party 1. Let S denote the gross revenues from sales and v the respective profit rate, implying that the net profits from sales are then $(v - r)S$ for party 2 and rS for party 1. We denote these profits (“values”) by $V_1 = rS$ and $V_2 = (v - r)S$.

This specification thus implies that a change in the one-way royalty r does not affect joint profits $V_1 + V_2 = vS$ of the two parties. Admittedly, this would not be the case if

[4] See, more generally, Muthoo (2006) for an overview of potential determinants of bargaining power.

a change in r affected the business strategies of the two parties. In particular, party 2 may respond to a higher royalty by adjusting the respective product prices. In case the two parties are in product market competition, a higher or lower royalty r may also affect the respective aggressiveness of party 1 on the product market.[5] In what follows, we abstract from this. One justification for this may be that in each considered bilateral negotiation, the respective parties may predominantly serve relatively different market segments (geographically but also with respect to technology and quality).

Joint profits $V_1 + V_2 = vS$ are thus the gross surplus from negotiations. How this surplus is split determines, in the present case, the royalty which induces to a profit transfer of rS from party 2 to party 1. By adjusting r, we can thereby fully trace out the so-called "bargaining frontier". The question is then at which point on this bargaining frontier should we expect that the two parties settle their negotiations. To answer this this question, we apply the Nash bargaining solution. According to this solution concept, there are two key determinants of bargaining power.

The first determinant are outside options which arise when negotiations "break down". We denote the respective profits in case of breakdown by B_1 and B_2 for the two parties. These are derived and discussed in the subsequent sections. Then, the difference

$$\begin{aligned} D &= (V_1 + V_2) - (B_1 + B_2) \\ &= vS - B_1 - B_2 \end{aligned} \tag{1}$$

denotes the net surplus, i.e., the profit that is realistically "on the table" and that the two parties can share. None of the two parties will accept an agreement that leaves it with less than the respective outside option, that is B_1 for party 1 and B_2 for party 2.

The second determinant of bargaining power concerns the way how the net surplus D is shared. We specify a sharing rule so that the share s_1 goes to party 1 and the share $s_2 = 1 - s_1$ goes to party 2. The sharing rule will be derived from "primitives" of the model below, following a standard extension of the model (cf. Appendix A).

Taking the sharing rule and the outside options presently as given, we thus have the following full description of the outcome of the bilateral negotiation over the one-way royalty r:[6] Party 1 realizes profits of $V_1 = B_1 + s_1 D$, i.e., the sum of the respective outside

[5] The scope for potentially mutually beneficial agreements to "raise rivals' costs" in order to thereby dampen competition has been largely explored in the literature (see, e.g., already in Katz (1987)).

[6] Precisely, we thus apply the asymmetric Nash-bargaining solution to a game with transferable utility. See, for instance, Muthoo (1999) for a general introduction.

option B_1 and the respective share s_1 of the net surplus D, and party 2 realizes profits of $V_2 = B_2 + s_2 D$, i.e., the sum of the respective outside option B_2 and the respective share s_2 of the net surplus D.[7] Keeping in mind that also $V_1 = rS$ and $V_2 = (v - r)S$ must hold (by definition), we thus have from the Nash bargaining solution that

$$r = \frac{B_1 + s_1 D}{S}. \tag{2}$$

2.2 Outside Options and the "Nash-in-Nash" Approach

To close the model for the moment, we thus need to determine each party's outside option, which is the outcome that arises when negotiations break down. In our application, break down refers to the step of proceeding to some costly dispute. For our model only two implications from this are relevant: First, the respective royalty will then no longer be determined by negotiations alone (e.g., by court order or as the outcome of arbitration). In a particular sense, which we will make precise, this will "anchor" the expected royalty rate. Second, this process will consume, potentially large, resources or may be costly also for other reasons (e.g., due to the involved uncertainty or due to production and sales losses in case of injunctions). In what follows, the outside options will thus be derived explicitly from a model of litigation, and the incurred costs of litigation or the arbitration process will be determined by the choice of the two parties' strategies in a Nash equilibrium.

We generally stipulate that under dispute the outcome is the product of two forces. Suppose first that during dispute the two parties would not produce any additional evidence or engage in other activities uncovering the value of the patent pool, which we do not need to specify in more detail for our purpose. We then suppose that the expected royalty, being denoted by R, is a linear function of the respective patent strength. As patent strength is denoted by x and as this applies to the patent pool of party 1, we can stipulate that $R = \gamma x_1$.

The second determinant of the outcome under dispute are the two parties' dispute activities, such as providing additional information or undertaking various (legal) steps, which will have an impact on the prevailing royalty rate and could thus, potentially, generate a gap between the outcome r and the previously introduced variable R.

We denote the costs ("losses") of party 1 by L_1 and those of party 2 by L_2. Both

[7] The two parties agree first of all to compensate each other for their outside options B_1 and B_2, and then the two parties agree to give each other their fraction s_1 and s_2 of the net surplus D.

the potential shift, $r - R$, and the respective costs, L_1 and L_2, are made more precise in the subsequent sections. The particular modeling choice introduced below will give rise to the following specific structure that we use already now to derive first implications from the Nash bargaining approach. We chose this structure for our presentation of results to highlight that, while all functional expressions are derived from primitives in what follows, the subsequent expression for the bargaining outcome, which may prove to be particularly useful for empirical strategies, may clearly also have other foundations.

Precisely, we first express the shift $r - R$ in terms of a percentage shift in relation to R (i.e., in terms of $\frac{r-R}{R}$). We now denote this by z and specify that this is proportional to S so that we can express the shift by the product zRS. Also the losses from the two sides' dispute activities are supposed to be proportional to "what is at stake", which is now denoted by a variable $l \geq 0$ so that we can write $L_1 = L_2 = lRS$. With this at hands, we can then write the outside option of party 1 as

$$B_1 = (1 + z)RS - lRS, \tag{3}$$

and the outside option of party 2 as

$$B_2 = vS - (1 + z)RS - lRS. \tag{4}$$

The "Nash-in-Nash" Approach. By combining in this way the Nash bargaining solution with the Nash equilibrium concept for the derivation of the outside options, we thus apply altogether a so-called "Nash-in-Nash" approach to model the particular bargaining situation. This is a commonly used approach in the applied bargaining literature and frequently also referred to as "hybrid" or as "bi-form" approach.[8]

For now, we obtain after substitution of the respective expressions for B_1 and B_2 from (3) and (4) that

$$\begin{aligned} D &= vS - B_1 - B_2 \\ &= 2lRS. \end{aligned}$$

Denoting now

$$g = z + l(2s_1 - 1), \tag{5}$$

and remembering that $R = \gamma x_1$, we obtain from (2) the following result:

[8] See, e.g., Brandenburger and Stuart (2007).

Lemma 1 *Applying the Nash bargaining solution to the determination of the one-way royalty r, and when outside options are determined by the reduced-form model of litigation, we obtain*

$$r = (1+g)R. \tag{6}$$

Note that the variable g represents a (percentage) shift factor, which is in favor of party 1 if $g > 0$ and in favor of party 2 if $g < 0$.

2.3 The Game of Litigation

We now introduce a simple model of litigation to endogenize the outside options. In the process of a dispute, the two parties can affect the respective outcome by undertaking respective strategies ("dispute efforts") e_1 and e_2. These strategies are costly, but their benefit is to move the outcome more closely to the one desired by the respective parties.

Precisely, in the spirit of the literature on contests,[9] we use the following "contest success function":

$$z := \frac{r-R}{R} = \mu \frac{e_1 - e_2}{e_1 + e_2}, \tag{7}$$

with $\mu > 0$. Hence, as party 1 exerts more litigation efforts, so that e_1 increases, then this will move upwards the expected royalty rate, as expressed in percentage terms on the left-hand side of (7). If party 2 increases its effort e_2, then this will reduce the right-hand side of (7), thus lowering the expected royalty rate. When $e_1 = e_2$, so that both parties exert the same effort, then we will have $r = R$. In this case, the two forces just cancel out, so that the same outcome arises as when there is no litigation effort, i.e., the royalty just reflects the strength of the underlying patents. We thus consider the activities during dispute as a contest. In line with the respective literature, we use the following functional specification for the costs that each party incurs when choosing the strategy e_i: $c_i(e_i) = k_i e_i$. Here, the parameters k_i are an inverse measure of the effectiveness of either side in influencing the outcome.

[9] Skaperdas (1996) coined this term, which comprises standard models of "rent seeking".

3 Equilibrium Analysis

3.1 Derivation of the Equilibrium

By solving for the Nash equilibrium of the litigation game and substituting this into the Nash bargaining solution, we arrive at the following characterization:

Proposition 1 *Consider the determination of one-way royalties through bilateral bargaining under the threat of litigation. Then, the respective royalty rate is determined as follows:*

$$r = (1+g)R,$$

with

$$g = \mu\frac{k_2 - k_1}{k_1 + k_2} + 2\mu\frac{k_1 k_2}{(k_1 + k_2)^2}(2s_1 - 1). \tag{8}$$

Proof. To obtain B_1 for party 1, we need to evaluate the net profit from (3) at (7):

$$B_1 = \left(1 + \mu\frac{e_1 - e_2}{e_1 + e_2}\right) RS - k_1 e_1, \tag{9}$$

and to obtain B_2 for party 2, we need to evaluate (4) at (7):

$$B_2 = vS - \left(1 + \mu\frac{e_1 - e_2}{e_1 + e_2}\right) RS - k_2 e_2. \tag{10}$$

We then obtain the precise values for B_1 and B_2 by substituting into these expressions the respective equilibrium values e_1^* and e_2^*. Note that the objective function is strictly concave. From the first-order conditions, we then have

$$k_i = 2\mu RS\frac{e_j^*}{(e_i^* + e_j^*)^2} \tag{11}$$

for $i, j \in \{1, 2\}$ with $i \neq j$, implying that $k_i e_i^* = k_j e_j^*$. Inserting the latter into (11) yields

$$e_i^* = 2\mu RS\frac{k_j}{(k_i + k_j)^2}. \tag{12}$$

Substituting (12) into (9) and (10) leads finally to

$$\begin{aligned} B_1 &= \left(1 + \mu\frac{k_2 - k_1}{k_1 + k_2}\right) RS - 2\mu\frac{k_1 k_2}{(k_1 + k_2)^2} RS, \\ B_2 &= vS - \left(1 + \mu\frac{k_2 - k_1}{k_1 + k_2}\right) RS - 2\mu\frac{k_1 k_2}{(k_1 + k_2)^2} RS. \end{aligned}$$

With the newly introduced notation

$$B_1 = (1+z)RS - lRS,$$
$$B_2 = vS - (1+z)RS - lRS.$$

we can now define

$$z = \mu\frac{k_2 - k_1}{k_1 + k_2}, \qquad (13)$$
$$l = 2\mu\frac{k_1 k_2}{(k_1 + k_2)^2}.$$

We now apply the Nash bargaining solution which is defined by (5) and (6). With the help of (13), the percentage shift factor $g = z + l(2s_1 - 1)$ simplifies to

$$g = \mu\frac{k_2 - k_1}{k_1 + k_2} + 2\mu\frac{k_1 k_2}{(k_1 + k_2)^2}(2s_1 - 1).$$

Hence, we have ultimately arrived at expression (8). ■

Recall that we consider presently the one-way royalty (or out-license) of party 1. We have, however, not indexed the respective variables accordingly. We do this now and write r_1 and x_1 (and thus R_1), but do not index g.

Consider now instead the negotiations over the out-license agreement for the patent pool of party 2. Note that now the perspective is changed: A royalty is now denoted by r_2 and induces a profit transfer from party 1 to party 2. The underlying determinants of bargaining power, which our model will make precise, are however still present, as summarized in the parameter g above. Thus, when party 1 has stronger bargaining power and thereby "tilts" r_1 to its favor, resulting in a higher value, now also r_2 should be "tilted" in favor of party 1, resulting in a lower value for r_2. The specifications in the formal model below yield now a very parsimonious outcome: The respective shift has the same "magnitude", albeit it is of different size (i.e., g versus $-g$). Precisely, we obtain more generally:

Corollary 1 *Considering separate negotiations over the one-way royalties of party 1 and party 2, we have*

$$r_1 = (1+g)\gamma x_1, \qquad (14)$$
$$r_2 = (1-g)\gamma x_2.$$

Proof. To obtain the outcome for the out-license of party 2, we can simply relabel all preceding expressions. While l from (13) remains unchanged, z is the same in absolute values but has obviously a different sign. That is, we now have $z = \mu \frac{k_1 - k_2}{k_1 + k_2}$. For this reason, we still leave the definition of z unchanged, but we now have due to the change in perspective that

$$\begin{aligned} B_1 &= vS - (1 - z)RS - lRS, \\ B_2 &= (1 - z)RS - lRS. \end{aligned}$$

Substituting this again into the Nash bargaining solution, we thus have for V_2 that

$$\begin{aligned} V_2 &= B_2 + s_2 D \\ &= [1 - z + l(2s_2 - 1)]\, RS \\ &= [1 - z - l(2s_1 - 1)]\, RS \\ &= (1 - g)RS, \end{aligned}$$

where we used that $s_2 = 1 - s_1$. As $V_2 = Sr$ still holds, this yields finally with the same parameters l, z and g as before

$$r = (1 - g)R, \tag{15}$$

where now, to recall, this applies to the out-license of party 2 so that $R = \gamma x_2$. ■

Before we discuss the implications of the equilibrium characterization, we briefly relate the sharing rule to potential primitives. For this, we introduce a model of alternating offers. This follows well-known results in the bargaining literature (also known as the “Nash program”). Accordingly, we think of various points in time $t = 1, 2, \ldots$ at which the two parties can make offers and respond to them. As this will not be important, we assume that party 1 begins to make an offer at $t = 1$. We denote the respective offer made by party 1 by $r^{(1)}$. If the offer is accepted, the respective agreement is implemented: party 2 agrees to pay $Sr^{(1)}$ (where S again refers to the expected revenues of party 2 to which the royalty applies). If party 2 rejects the offer, the game proceeds into the next round, that is $t = 2$. It is then party 2's turn to make an offer of $r^{(2)}$. Again, if this is accepted, then the respective agreement is implemented, leading to a payment of $Sr^{(2)}$. If no agreement is struck in $t = 2$, we proceed to $t = 3$, at which it is again up to party 1 to make an offer. Thus, more generally, in odd periods, starting with $t = 1$, the respective offer is made by party 1, while party 2 makes the offer in even periods. To complete the description of the framework, as is standard, we consider the respective periods $t = 1, 2, \dots$ to be equally spaced apart in "real time", that is at distance $\Delta > 0$.

Crucially, the rejection of an offer may trigger breakdown of negotiations, and delaying negotiations can be additionally costly for the two parties. This requires some additional specifications. When party 2 rejects an offer (in odd periods $t = 1, 3, \dots$), we specify that negotiations break down with probability $0 < f_1 < 1$. On the other hand, rejection by party 1 leads to a breakdown with probability $0 < f_2 < 1$. The respective probabilities can be interpreted as the willingness of each party to proceed to litigation or equivalent procedures, e.g., based on the respective resources or reputation (that the party has or wants to build up). Once breakdown is triggered, the respective expected profits of either party are, as previously, given by B_1 and B_2. The respective risk of breakdown depends on time, where for small Δ we write the respective probability of breakdown as $f_1 = \lambda_1 \Delta$ and as $f_2 = \lambda_2 \Delta$, respectively.[10] We describe in Appendix A how this results, as $\Delta \to 0$, in the sharing rule

$$s_1 = \frac{\lambda_1}{\lambda_1 + \lambda_2}, \tag{16}$$

and thus

$$s_2 = 1 - s_1 = \frac{\lambda_2}{\lambda_1 + \lambda_2}.$$

This allows in turn to rewrite

$$g = \mu \left[\frac{k_2 - k_1}{k_1 + k_2} + \frac{2k_1 k_2}{(k_1 + k_2)^2} \frac{\lambda_1 - \lambda_2}{\lambda_1 + \lambda_2} \right]. \tag{17}$$

3.2 Implications of the Characterization

Recall that we identified two determinants of bargaining power: outside options and the sharing rule.

Suppose now that the outside option of party i deteriorates. In our model, this coincides with an increase in k_i, which means that it is now more costly for party i to engage in litigation. As this harms party i's bargaining power, we can show that, in equilibrium,

[10] These are approximations when the likelihood of breakdown is constant overtime (i.e., when it follows a Poisson process).

both royalties are "tilted" (symmetrically) in favor of the other party j:

$$\begin{aligned}\frac{dr_i}{dk_i} &= \frac{d(1+g)\gamma x_i}{dk_i}\\ &= \gamma x_i \frac{dg}{dk_i}\\ &= -4\mu\gamma x_i \left[\frac{k_j(k_i\lambda_i + k_j\lambda_j)}{(k_i+k_j)^3(\lambda_i+\lambda_j)}\right] < 0,\end{aligned}$$

$$\begin{aligned}\frac{dr_j}{dk_i} &= \frac{d(1-g)\gamma x_j}{dk_i}\\ &= -\gamma x_j \frac{dg}{dk_i}\\ &= 4\mu\gamma x_j \left[\frac{k_j(k_i\lambda_i + k_j\lambda_j)}{(k_i+k_j)^3(\lambda_i+\lambda_j)}\right] > 0.\end{aligned}$$

Thus, a party's bargaining power is decreasing in its litigation costs and increasing in its opponent's litigation costs. Notably, higher costs for dispute imply that revenues from licensing decrease due to lower own royalties, while the costs for using licenses increase due to higher third-party royalties. Thus, a decrease in a party's bargaining power harms revenues in two ways, however, the magnitude of these two effects is the same.

As discussed above, also the sharing rule affects the bargaining outcome and thus royalties. In our model, the sharing rule is crucially linked to the parameter λ_i, which captures the risk of breakdown as $f_i = \Delta\lambda_i$. A standard interpretation is in terms of parties' "aggressiveness". Intuitively, a party who anticipates a higher risk of breakdown when its possibly not favorable offer is rejected by the counterparty is relatively more willing to strike an agreement. We expect that this has a positive effect on bargaining power, implying that a more aggressive party finds it easier to tilt royalties in its favor. Simple comparative statics confirm our intuition:

$$\begin{aligned}\frac{dr_i}{d\lambda_i} &= \frac{d(1+g)\gamma x_i}{d\lambda_i}\\ &= \gamma x_i \frac{dg}{d\lambda_i}\\ &= 4\mu\gamma x_i \left[\frac{k_i k_j \lambda_j}{(k_i+k_j)^2(\lambda_i+\lambda_j)^2}\right] > 0,\end{aligned}$$

$$
\begin{aligned}
\frac{dr_j}{d\lambda_i} &= \frac{d(1-g)\gamma x_j}{d\lambda_i} \\
&= -\gamma x_j \frac{dg}{d\lambda_i} \\
&= -4\mu\gamma x_j \left[\frac{k_i k_j \lambda_j}{(k_i + k_j)^2(\lambda_i + \lambda_j)^2}\right] < 0.
\end{aligned}
$$

We have thus shown that royalties are not only the outcome of patent strength (as would be when $r = \gamma x$). There are other determinants, notably outside options (captured by k_i) and negotiating skills (captured by λ_i), affecting bargaining power and thus royalties. Lastly note that only when the two parties are equally effective in litigation and equally aggressive (i.e., $k_i = k_j$ and $\lambda_i = \lambda_j$ so that $g = 0$), patent strength is the only determinant of royalties. We summarize our results as follows:

Corollary 2 *Ceteris paribus, party i obtains a higher own (out-license) royalty and has to pay a lower royalty for the other party j's license when it is relatively more successful in litigation (lower k_i or higher k_j) or relatively more aggressive in turning to litigation (higher f_i or lower f_j).*

While generally the lack of publicly available royalty data heavily limits empirical research, Sakakibara (2010) is an exception, as she has access to a dataset with over 600 Japanese patent licensing contracts up to 2003. Sakakibara (2010) finds that profitability characteristics of the patent and (relative) bargaining power of negotiators are good predictors of royalty rates. Her first determinant corresponds to patent strength in our framework. More precisely, she finds that widely applicable patents are also associated with higher royalties. To quantify the second determinant, she uses the opportunities that are available to a licensor as a proxy (which may, for instance, be rather limited if a licensor specializes in innovation and thus cannot bring a product to market on its own).[11] According to Sakakibara (2010), this may explain why research organizations tend to receive lower royalty rates. In contrast, our analysis considers litigation as a breakdown point or outside option.

The analyzed formal model shows how royalties may be determined by various factors that in turn affect parties' bargaining power. Royalties should thus be interpreted also in

[11] The role of (relative) bargaining power as a "stylized fact" has also been noted by industry observers. For instance, Granieri et al. (2011, p. 240) note that "the structure and thus the value of a patent license greatly depends on the relative bargaining powers of the parties, whose potential issues must be understood and discussed before introducing the economic valuation methods."

light of these potential determinants, rather than being only the result of "hard factors" such as patent strength. In Appendix B we briefly review literature in Industrial Organization that has tried to back-out such additional determinants, affecting bargaining power in other contexts, notably by estimating the respective sharing rule.

4 Concluding Remarks

In this paper, we studied the effect of (relative) bargaining power on the determination of royalties. In general, we identify the outside options and the risk of breakdown as determinants of bargaining power. In particular, we endogenize these two determinants by deeper parameters of the economic situation, e.g., different willingness and ability to litigate.

Our model highlights the importance of (relative) bargaining power: Ceteris paribus, the party that is relatively more successful in litigation or that is relatively more aggressive in turning to litigation obtains also more favorable royalties. Thus, we show that there are multiple factors affecting bargaining power and in turn royalties, apart from pure patent strength.

Besides, the literature discusses further determinants of bargaining power such as impatience or inside options. The effect of impatience on bargaining power and thus on royalties is similar to the one of aggressiveness. The less patient party, which may possess fewer financial resources, is also more willing to strike an agreement. On the other hand, inside options account for the benefits that the parties obtain during the bargaining procedure. Similar to outside options, the party with the relatively better inside option is also more effective in tilting the bargaining outcome to its favor.

Finally, note that our model (as well as the Nash bargaining theory) relies on the assumption of symmetric information. For instance, in the (realistic) case that the "true" patent strength is only known to the licensor, an agreement may not be reached, even though it would be mutually beneficial.

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Appendix A Endogenizing the sharing rule (s_1,s_2)

We now provide more details for the (subgame perfect) equilibrium characterization of the alternating offer bargaining model, as specified in the main text. As is well known, the respective strategies are uniquely specified and lead to an agreement in the first period of the model. We provide a well-known constructive proof.[12] It relies on what each party anticipates what would happen in case it made a different offer or rejected an offer.

Consider thus an odd period, where party 1 makes an offer. To ensure that the respective offer $r^{(1)}$ is indeed accepted, party 2 must be kept at least indifferent between accepting and rejecting the offer. Optimally, the offer makes party 2 just indifferent. For this to be the case, the profits of party 2 from accepting the offer, $(v - r^{(1)})S$, must thus be equal to the profits from rejecting the offer, which are

$$(1 - f_1)(v - r^{(2)})S + f_1 B_2,$$

i.e., the profits from continuation of negotiations, which is then expected to end in the next period with acceptance of the offer r_2 made by party 2, and the profits after breakdown of negotiations, B_2, where each term is multiplied with the respective probability f_1 (for breakdown) and $1 - f_1$ (for continuation). Hence, we have

$$(v - r^{(1)})S = (1 - f_1)(v - r^{(2)})S + f_1 B_2. \tag{18}$$

We can derive next an analogous requirement for the offer $r^{(2)}$, which now must keep party 1 at least indifferent.[13] As party 1 realizes the profits $r^{(2)}S$ under the respective offer, and as the expected profits are

$$(1 - f_2)r^{(3)}S + f_2 B_1$$

in case of rejection, to make party 1 indifferent between acceptance and rejection, it must hold that

$$r^{(2)}S = (1 - f_2)r^{(1)}S + f_2 B_1, \tag{19}$$

where we used that $r^{(1)} = r^{(3)}$, i.e., offers are stationary.[14] We can now use the two requirements (18) and (19) (the so-called "indifference conditions") to solve these for $r^{(1)}$

[12] This goes back to Shaked and Sutton (1984).

[13] This construction of the equilibrium outcome does not prove uniqueness. The proof of uniqueness is obtained by adding the supremum or infimum, respectively.

[14] This is line with the basic alternating-offers model of Rubinstein (1982), where, in equilibrium, each player makes the same offer whenever an offer has to be made.

and $r^{(2)}$. For $r^{(1)}$ this yields after transformations

$$r^{(1)}S = \frac{Svf_1 - f_1B_2 + f_2(1-f_1)B_1}{1-(1-f_1)(1-f_2)}. \tag{20}$$

Recalling that $f_1 = \lambda_1\Delta$ and $f_2 = \lambda_2\Delta$, we obtain from l'Hospital's rule as a (limit) result the respective sharing rules.

Proof. First, note that we can rewrite (20) as

$$r^{(1)}S = \frac{Sv\lambda_1\Delta - \lambda_1\Delta B_2 + \lambda_2\Delta(1-\lambda_1\Delta)B_1}{1-(1-\lambda_1\Delta)(1-\lambda_2\Delta)}. \tag{21}$$

Second, let $f(\Delta)$ denote the numerator and $g(\Delta)$ the denominator of (21). Since

$$\lim_{\Delta\to 0} f(\Delta) = \lim_{\Delta\to 0} g(\Delta) = 0,$$

as well as $f(\Delta)$ and $g(\Delta)$ are both differentiable, we can apply l'Hospital's rule, which states that

$$\lim_{\Delta\to 0}\frac{f(\Delta)}{g(\Delta)} = \lim_{\Delta\to 0}\frac{f'(\Delta)}{g'(\Delta)}.$$

Taking the respective derivatives yields

$$\frac{f'(\Delta)}{g'(\Delta)} = \frac{Sv\lambda_1 - \lambda_1B_2 + \lambda_2B_1 - 2\lambda_1\lambda_2\Delta B_1}{\lambda_1+\lambda_2-2\lambda_1\lambda_2\Delta}.$$

This implies that in the limit, when Δ is arbitrarily small, party 1's profits from (21) converge to

$$\frac{Sv\lambda_1 - \lambda_1B_2 + \lambda_2B_1}{S\left(\lambda_1+\lambda_2\right)}. \tag{22}$$

Recall that the Nash bargaining solution from (2) can be simplified with (1) to

$$rS - B_1 = s_1(vS - B_1 - B_2). \tag{23}$$

Substituting (22) into (23) then yields

$$s_1(vS - B_1 - B_2) = \frac{\lambda_1}{\lambda_1+\lambda_2}(vS - B_1 - B_2),$$

from which we obtain

$$\begin{aligned} s_1 &= \frac{\lambda_1}{\lambda_1+\lambda_2}, \\ s_2 &= 1 - s_1 = \frac{\lambda_2}{\lambda_1+\lambda_2}. \ \blacksquare \end{aligned}$$

Appendix B Review of Literature Documenting Differences in Bargaining Power

As noted in the Introduction, the literature on Industrial Organization has not only documented differences in bargaining power as key determinants of prices, but has also tried to estimate the sharing rule. In this Appendix we provide a brief discussion of several such contributions, which are first summarized in Table 1:

Table 1: Ranges of estimated sharing rules in the literature

Negotiations between	Contribution	Range of estimated sharing rules in bilateral negotiations
Manufacturers and retailers	Draganska et al. (2010)	[0.26-0.8] Retailer perspective
	Haucap et al. (2013)	[0.35-0.92] Retailer perspective
	Bonnet and Bouamra-Mechemache (2016)	[0.2-1] Retailer perspective
Television channels and distributors	Crawford and Yurukoglu (2012)	[0.17-0.77] Distributor perspective
Hospitals and suppliers	Grennan (2013)	[0.08-0.71] Supplier perspective
Hospitals and MCOs	Gowrisankaran et al. (2015)	[0.03-1] MCO perspective

The literature shows indeed that a wide variety in sharing rules across individual bilateral negotiations may prevail. We now discuss the selected examples in turn.

In an empirical analysis of bilateral negotiations between ground coffee manufacturers and large retailers in Germany in 2000 and 2001, Draganska et al. (2010) show that the retailers' share varies from 26% to 80%. Haucap et al. (2013), following the framework of Draganska et al. (2010), also conclude that manufacturers and retailers do not have identical bargaining power. They show that retailers manage to extract on average 76% of the surplus. Bonnet and Bouamra-Mechemache (2016) apply the framework developed by Draganska et al. (2010) to the French liquid milk market. Depending on the manufacturer-retailer pair, a retailer can obtain from 20% to 100% of the incremental surplus, a manufacturer thus from 0% to 80%.

Based on empirical evidence from the market for subscription-based television services, Crawford and Yurukoglu (2012) conclude that bargaining power and the sharing rule are not equally distributed between two parties to a negotiation. The authors find that, depending on the content provider-distributor pair, a content provider can extract between 23% and 83% of the surplus, so that distributors can obtain between 17% and 77%.

Moreover, Grennan (2013) and Gowrisankaran et al. (2015) provide empirical evidence of bargaining power in the health care sector. Grennan (2013), using data on negotiations between hospitals and providers of coronary stents, shows that hospitals on average have greater bargaining power than suppliers, as they manage to extract on average 67% of the surplus. Gowrisankaran et al. (2015) analyze bilateral bargaining between hospitals and managed care organizations (MCOs). Their estimates suggest that bargaining power varies greatly across hospitals and MCOs, as a MCO can extract from 3% to 100% of the surplus.

In addition to the reported findings which document notably a large heterogeneity in surplus shares across negotiators and negotiations, some of these papers have also looked more specifically for the respective determinants. For manufacturer-retailer relationships, Meza and Sudhir (2010) find that (strategic) factors such as store-brand positioning, the presence of private labels or assortment depth significantly affect bargaining power. Also Grennan (2014) takes a closer look on the sources of bargaining power of hospitals. He argues that bargaining power seems to be a firm specific capability.[15]

[15] His conclusion also rests on the finding that, despite substantial differences in the estimated sharing rule, none of the available hospital characteristics such as census region, teaching/nonteaching status, public/private or size in terms of number of diagnostics procedures performed has meaningful explanatory power.