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Are Joint Patents Collusive?
Evidence from the US and Europe

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ABSTRACT

We investigate whether patents that are jointly held by legally independent companies help sustain product-market collusion. We use a simple model of repeated interactions to show that joint patents can serve collusive purposes. Our model generates two testable predictions: when joint patents are held for collusive purposes, a) there is a positive relationship between the propensity to jointly own a patent and proximity in the product market; b) joint patents are associated with less licensing in the market for technology than individually owned patents, especially when firms are close product-market competitors. We construct a large, novel dataset that contains information on patents, research joint ventures, and licensing at the firm-level for the US and the EU to validate our theoretical predictions. We exploit differences in the legal regimes applicable to joint patents in the US and Europe to show that the data is consistent with our theoretical predictions.

KEYWORDS: Joint patents; Property rights; R&D cooperation; Licensing

JEL Classification: K11; O31; O34

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1 Introduction

Patents that are owned jointly by legally independent companies are rare.[1] In our data, we find patents owned jointly by legally independent companies to account merely for a share of about 1.5 and 4 percent of all patents held by private companies in the US and in Europe respectively.[2]

This, however, does not automatically imply that joint patents are economically irrelevant. First, as is well known in the patent literature, the value distribution of patents is extremely skewed (Schankerman and Pakes, 1986). There is the possibility that joint patents protect particularly valuable inventions. Second and related, joint patents are commonly the outcome of underlying research cooperation. Hence, they may serve additional purposes beyond the protection of the underlying technology, such as the provision of incentives for maximizing investment into joint research (Belderbos et al., 2012). Third, sharing ownership of patents may change firms' incentives to exploit the intellectual property both in the technology market and the product market.

This suggests at least three potential explanations for why firms file a joint patent. First, the prospect of joint ownership of a patent may provide optimal incentives at the innovation stage. This may increase the likelihood of a successful invention and lead to a high-value innovation. Second, it could be that available alternatives of allocating intellectual property rights result in lower profits. For instance, a joint patent may facilitate or hinder licensing (depending on the legal regime in place) and thus help the firms to implement the best strategy in the technology market. Third, joint patents may help sustain collusion if co-assignees can freely license the patented technology to third parties – without the consent of the other co-assignee(s) – to punish any deviation from the collusive agreement. This third explanation may be relevant in the US, where the decision to license a joint patent to third parties cannot be opposed by any of the owners. Moreover, the licensor does not have to share the profits earned through the licensing fees.

In this paper, we focus on the latter of potential explanations for the existence of joint patents. We propose a simple model that shows that product-market rivals might have collusive incentives to file joint patents, and we explore the conditions

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[1]We are interested exclusively in patents held jointly by legally independent private companies; we are not concerned with joint patenting by private firms with, for example, universities or other public research institutions. Our focus is on co-ownership of the property right a patent represents which is distinct from joint inventorship which defines the intellectual right to the invention.

[2]Our figures accord with the scarce available empirical evidence. Hagedoorn (2003) finds a share of 1.3 percent (1989-1998) and Hicks and Narin (2001) a share of .2% in 1980 and 1.3% in 1999 of US patents to be jointly owned.

under which this is more likely to occur. We present empirical evidence that is broadly consistent with the model's predictions.

To show that joint patents can be used by product market competitors as a vehicle to help sustain collusion, we analyze the interaction between two firms that are engaged in a research joint venture (RJV) and have to decide between (a) filing a joint patent and (b) assigning the patent to one party and granting an exclusive licensing agreement to the other.[3] The latter solution eliminates any further licensing, while the former allows, under the US regime, both firms to license out without the consent of the co-assignee. In a setting where firms are Cournot competitors in the product market and the licensor and its licensees sell indistinguishable varieties, joint profits are maximized with zero licensing. This implies that there is no reason for firms to choose a joint patent other than its potential role in sustaining collusion. We show that holding a joint patent lowers the Nash equilibrium profits that a breaching firm can earn after collusion has broken down because a joint patent triggers aggressive licensing by both co-assignees. Absent veto power (US regime) to control licensing by the co-assignee, joint patents can create incentives for each co-assignee to license out the technology and thereby trigger a race to the bottom. This happens because licensing has negative externalities for the co-owners which the firm that licenses out does not take into account. However, the extent of licensing decreases when firms are more differentiated. Thus, the further away are co-assignees in the product space, the less costly is a deviation from the collusive agreement. We contrast this outcome with the case in which joint patents do not help sustain collusion and positive licensing might maximize firms' joint profits. In this case, joint patents are less likely to be chosen the closer are the firms in the product space because a joint patent would lead to a race to the bottom in licensing that destroys all profits.

Our model also offers interesting implications for firms' behavior in the market for technology. When joint patents are motivated by collusion, they should be associated with little licensing; licensing should only occur in case of deviation from collusion. Instead, when joint patents are not used as a vehicle to sustain collusion despite the absence of veto power, joint patents should be associated with weakly more licensing relative to single-owned patents, especially when firms are close product-market competitors.

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[3]Generally speaking, RJVs give firms plenty of opportunities to coordinate behavior and to extend this coordination onto the product market. For example, a RJV can centralize decision making by facilitating the exchange of information relevant for competition between members or by combining collaborative efforts with control over competitively significant assets. The available empirical evidence supports the notion that RJVs can serve a collusive function (Goeree and Helland, 2009).

To verify whether our predictions are consistent with empirical data, we exploit the fact that the legal regime in the majority of European countries differs from the US. In most European countries co-owners have veto power, that is, they can veto any decision to license out the technology. We rely on this difference between the legislations governing the ownership of joint patents in the US and in Europe, to identify the collusive effect of joint patents. For this purpose, we construct a large dataset that contains firm-level information on firms' patent filings, RJVs, and licensing activity for the US and five major European economies,[4] covering the period 2000-2004 and 2000-2006 respectively.

Our empirical findings suggest a striking difference in the frequency of joint patents between firms in the US and firms in Europe. Joint patents account for less than 1.5 percent of total USPTO filings by US companies in our dataset. In contrast, around 4 percent of patents held by our European firms are jointly owned. In the US, joint patents are by far most frequent in the pharmaceutical and chemical industry, as well as in the electronic instruments and communication equipment industries. The latter two are industries with a history of collusion coupled with high RJV participation (Goeree and Helland, 2009). In Europe, joint patents are more widely used across all industries, with machinery and engines as well as business and engineering services filing the largest share of jointly held patents. Our results suggest that firms that are direct product-market competitors are more likely to file for a joint patent than companies across industries. This is true for both the US and Europe and most likely reflects complementarities in conducting joint research. However, the positive correlation between the propensity to co-assign a patent and product-market proximity in the absence of veto power in the US means that the data do not reject our hypothesis of joint patents serving collusive purposes. To corroborate these findings, we also analyze firms' out-licensing activity. If the motivation to co-assign patents among product-market competitors is mainly driven by research complementarities, firms should not be observed to license co-assigned patents less frequently than individually-owned patents regardless of the existence/absence of veto power. If, however, co-assigned patents are also used for collusive purposes in the absence of veto power, we should see less licensing by firms that hold co-assigned patents. This is supported by our descriptive evidence on firms' licensing activity. In the US, firms that share the ownership of patents tend to license less than firms that hold only individually-owned patents. In Europe, in contrast, there is no significant negative correlation between a firm's licensing activ-

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[4]The countries included are France, Germany, the Netherlands, Switzerland, and the United Kingdom.

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ity and the co-assignment of patents. Therefore, the data is broadly consistent with our theoretical predictions which support the view that co-assigned patents may be used by companies for collusive purposes. Nevertheless, as also evidenced by our analysis, product-market collusion is certainly not the only, and likely not the most frequent motivation for the co-assignment of a patent.

Surprisingly, joint patents have received scant attention in the existing literature. The available evidence on joint patents is limited to a descriptive analysis of the extent of joint patenting and corresponding firm characteristics. There is little analysis with regard to the determinants of firms' decision to jointly own a patent and the purpose of the co-assigned property right.[5] This paucity of evidence stands in stark contrast to the profuse literature on RJVs, and the substantial body of theoretical research and empirical evidence on a range of mechanisms employed by firms to share and exchange patents including cross-licensing agreements (Giuri and Torrisi, 2010), patent pools (Layne-Farrar and Lerner, 2011), and patent commons (Hall and Helmers, 2011). Our analysis, therefore, adds to the empirical literature on the sharing and exchange of patents between companies by shedding light on the role played by shared ownership of patents. Moreover, testing our theoretical predictions has antitrust-policy relevance with regard to the interaction of patents and product-market competition. Our analysis also offers evidence on the relationship between participation in RJVs and product-market collusion by highlighting those RJVs between product-market rivals with a particularly high potential for collusion.

The remainder of this paper is organized as follows. Section 2 briefly explains the legal framework that governs the joint ownership of patents in the US and Europe. Section 3 contains a theoretical analysis of the role that joint patents may play in sustaining collusion between product-market rivals. Section 4 describes the dataset used to test the theoretical predictions. Section 5 shows our empirical results and Section 6 briefly concludes.

2   Legal Background

From a legal point of view, there are no restrictions in either the US or Europe on the joint ownership of patents *per se*, and their treatment does not differ from that of any other shared property rights. This is interesting for two reasons. First, Article 101, 1, of the Treaty on the Functioning of the European Union stipulates that agreements between firms, including RJVs, are prohibited if they have anticompetitive effects. The statement of facts contained in Article 101, 1, however, does not apply with

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[5]See Duguet (1994), Hicks and Narin (2001), Hagedoorn (2003), and Kim and Song (2007).

regard to joint patents. Second, patents can be used for anticompetitive behavior, e.g. by means of imposing important entry barriers, and are thus subject to the legal provisions in Article 102 that regulate competition. Joint patents contain both elements: an inter-firm agreement and a patent right. Despite the resulting potential for anti-competitive behavior from holding joint ownership of intellectual property, joint patents are not directly subject to any specific regulations other than the separate regulations in place for RJVs and intellectual property rights. The underlying assumption is that joint patents do not require any additional regulatory intervention beyond the existing regulations on the process by which joint patents are usually created, i.e., RJVs, and on the use and assertion of individual property rights by their individual owners.

The legal framework for joint ownership, however, differs across countries. This implies that the allocation of rights to individual owners of a joint patent differs across countries. While in all jurisdictions joint owners have the same rights regardless of their actual underlying contribution to the patent and are entitled to using the patented invention for their own purposes, regulations differ above all with respect to re-assignment and licensing to third parties. In the US, each of the joint owners can exploit the protected invention, which includes the non-exclusive licensing of the patent, without the consent of the other owners (35 U.S.C. §262). In the European Union, the legal treatment of joint patents differs from the US. For instance, German Law also allows each owner to exploit the protected invention individually including its re-assignment, but German firms cannot license the jointly owned patent without the consent of the co-assignee (§ 744 BGB). The regulations with regard to licensing are the same in the UK (The Patents Act, Section 36.3), France (Article L. 613-32 Code de la Propriété Intellectuelle),[6] the Netherlands (Art. 66 Patent Act 1995), and Switzerland (Art. 34.2 Bundesgesetz über die Erfindungspatente). Note that these national rules also apply to patents that were granted by the European Patent Office (EPO), because any patent granted by the EPO has to be validated with the national patent office of any member state of the European Patent Convention (EPC). This means that the EPO patent turns into a national patent right that is subject to national legislation.

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[6]In the case of France, a co-assignee may oppose the grant of a non-exclusive license only under condition that he 'buys out' the co-assignee that desires to grant a license. Exclusive licenses can be vetoed without the 'buy out' obligation (Article L. 613-29 Code de la Propriété Intellectuelle).

3 Model

In this section, by means of a simple model, we show that joint patents may facilitate collusion among incumbents in the product market and explore the conditions under which this is particularly likely to occur. The key to our argument is that competition in the product market creates a strategic incentive to license. Licensing the technology to a market entrant increases the licensor's share of product-market profits but, at the same time, erodes industry profits. While the erosion of profits is shared between rivals, the profits from licensing accrue entirely to the licensor. Each incumbent then has an incentive to license, although joint profits would be higher in the absence of any licensing. Hence, if the incumbents hold a joint patent in a regime without veto power, competition is tougher and profits are lower than in a regime with veto power, where each incumbent can block the licensing of its rival, or if the patent is single-owned. Without veto power, incumbents have thus no incentives to file a joint patent unless they interact repeatedly in which case a joint patent may serve a collusive function by harshening the punishment in case one firm breaches the collusive agreement.

In our analysis, we focus on the decision on the type of patent (joint or single-owned) that is filed to protect the invention generated by the RJV. We therefore assume that the firms have already engaged in a RJV and generated a patentable invention.

3.1 Set-Up

We consider two symmetric incumbent firms $i = 1, 2$ that hold a joint patent and serve the same product market. The incumbents play the same stage game over an infinite horizon $t = 0, 1, 2, \ldots$, and in each period t, they can choose to collude or to compete. The incumbents use the patented technology to produce a good which can be either perfectly homogenous or differentiated. Along the lines of Arora and Fosfuri (2003), we assume that, besides the two incumbents, many potential market-entrants exist. Entrants do not have any innovative capability but can produce the good if they receive a license for the use of the technology from one of the incumbents. A licensee produces the same variety of the good as the original licensor. The incumbents can both produce the good themselves and license out their technology to potential entrants.[7]

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[7]In some industries, e.g. chemicals, semiconductors and computers, licensing is important as a means of generating revenues of innovations. In many instances, the firms in these industries license their technology to other firms that can potentially compete with them (Arora and Fosfuri, 2003).

Let $k_i \geq 0$ be the number of non-exclusive licenses sold by incumbent $i = 1, 2$. Hence, the total number of product-market competitors is $k_1 + k_2 + 2$. For analytical tractability, we consider k_i to be a continuous variable. We assume that an incumbent makes a take-it-or-leave-it offer to a potential entrant and extracts all the net surplus generated by the use of the technology through an upfront fixed fee. In particular, we do not consider contracts with per-unit royalties, and we assume that licensing does not involve any transaction costs.

Each period, the game consists of two stages. In the first stage, each incumbent independently decides how many potential entrants she wishes to license the patented technology to. We distinguish between two property-right schemes, namely *veto power* and *no veto power*, which correspond to the European and US legal frameworks respectively. In the regime with veto power, each individual decision to license the joint patent can be vetoed by the co-assignee. In the regime without veto power, not only does each incumbent freely choose how many licenses she wants to sell but also she can keep all the profits earned from licensing to herself. In the second stage, all the firms that have acquired the technology in the first stage produce the good and compete in quantities.

We assume that the alternative to filing a joint patent is one incumbent filing a single-owned patent and granting an exclusive license to the other company. No further licenses can be sold, and the incumbents produce the good in a (differentiated) Cournot duopoly. We take this scenario as our benchmark case. Hence, when the patent is single-owned, the first stage is absent. The outcomes under a joint and a single-owned patent differ if the joint patent induces licensing and thereby market entry which in turn intensifies product-market competition.

Denote the infinitely repeated game with a joint patent by $\Gamma_\infty^{jp}(\pi^{jp}, s^{jp})$ and the infinitely repeated game with a single-owned patent by $\Gamma_\infty(\pi, s)$. The incumbents are able to sustain a collusive outcome as an equilibrium when the payoff from collusion is no less than the payoff from a unilateral deviation. To examine the effect of jointly-held patents on the ease of collusion, we compare the incentive-compatibility constraint of the incumbents in $\Gamma_\infty(\pi, s)$ to that in $\Gamma_\infty^{jp}(\pi^{jp}, s^{jp})$.

The repeated-game payoff of incumbent i when choosing strategy $s_i = (q_i^1, q_i^2, \ldots)$ when the rival $j \neq i$ plays strategy s_j is given by $\Pi_i(s_i, s_j) = \sum_{t=1}^\infty \delta^{t-1} \pi_i(q_i^t, q_j^t)$, where $\pi_i(q_i^t, q_j^t)$ is incumbent i's payoff in period t, a function of incumbent i's action at t, q_i^t, and the action of the rival at t, q_j^t. The incumbents discount the future at the common discount factor $\delta \in (0, 1)$. Similarly, the repeated-game payoff of incumbent i when choosing $s_i^{jp} = (q_i^1, q_i^2, \ldots; k_i^1, k_i^2 \ldots)$ when the rival plays s_j^{jp} is given by $\Pi_i^{jp}(s_i^{jp}, s_j^{jp}) = \sum_{t=1}^\infty \delta^{t-1} \pi_i^{jp}(q_i^t, k_i^t, q_j^t, k_j^t)$.

We consider a subgame-perfect collusive equilibrium in which the incumbents use grim trigger strategies. These strategies imply that, if one incumbent unilaterally deviates from the collusive agreement, the other punishes this deviation by reverting to the Nash equilibrium of the stage game in the following period and forever after. Each incumbent i in $\Gamma_\infty(\pi, s)$ plays her collusive strategy $s_i^c = (q_i^c, q_i^c, \ldots)$ if the payoff from collusion $\pi_i(q^c)/(1 - \delta)$ is no less than the payoff from deviation which consists of the one-shot gain from deviating - by playing the best response to q_j^c - $\pi_i(BR_i(q_j^c), q_j^c)$ plus the discounted payoff from punishment $\delta\pi_i(q^n)/(1 - \delta)$. The incentive-compatibility constraint is thus given by

$$\pi_i(BR_i(q_j^c), q_j^c) + \frac{\delta}{1 - \delta}\pi_i(q^n) \leq \frac{1}{1 - \delta}\pi_i(q^c).$$

Solving for δ we get

$$\widetilde{\delta} \equiv \frac{\pi_i(BR_i(q_j^c), q_j^c) - \pi_i(q^c)}{\pi_i(BR_i(q_j^c), q_j^c) - \pi_i(q^n)} \leq \delta. \tag{1}$$

where $\widetilde{\delta}$ is the critical discount factor above which collusion can be sustained. Hence, incumbents are able to successfully collude if they value future flows of collusive profits sufficiently such that $\widetilde{\delta} \leq \delta$.

The same reasoning applies when the incumbents hold a joint patent. An incumbent i plays the collusive strategy $s_i^{cjp} \equiv (q_i^c, q_i^c, \ldots; k_i^c, k_i^c \ldots)$ in $\Gamma_\infty^{jp}(\pi^{jp}, s^{jp})$ using a grim trigger strategy as long as the following incentive-compatibility constraint holds:

$$\widetilde{\delta}^{jp} \equiv \frac{\pi_i^{jp}(BR_i(q_j^c, k_j^c), q_j^c, k_j^c) - \pi_i^{jp}(q^c, k^c)}{\pi_i^{jp}(BR_i(q_j^c, k_j^c), q_j^c, k_j^c) - \pi_i^{jp}(q^n, k^n)} \leq \delta. \tag{2}$$

We compare the critical discount factors in (1) and (2) to characterize the impact of a joint patent on the sustainability of collusion in the product market. A joint patent facilitates collusion if the collusive strategy can be sustained at a lower critical discount factor when incumbents hold a joint patent than when they hold a single-owned patent and act as Cournot duopolists. Moreover, as this critical threshold decreases it becomes easier to sustain collusion with a joint patent.

3.2 Collusion and the Propensity to File Joint Patents

Consider first the benchmark case in which the incumbents compete in a symmetric Cournot duopoly. We assume that each incumbent i faces the following linear market

demand:

$$p_i(q_i, q_j) = a - q_i - \mu q_j,$$

where p_i and q_i denote the price and the quantity respectively and $a > 0$ is the demand intercept. A key parameter is $\mu \in [0, 1]$ which captures the degree of product differentiation. For $\mu = 1$ the products are perfect substitutes, and they become more differentiated as μ decreases. For $\mu = 0$ the incumbents act like two monopolists on two separate markets. We normalize the unit costs of production to zero.

When the incumbents hold a joint patent, they have the possibility to license the technology which induces market entry and increases the number of product-market competitors. Each incumbent i then faces the following market demand:

$$p_i(q_i, q_j) = a - \sum_{k_i+1} q_i - \mu \sum_{k_j+1} q_j,$$

where the first summation is across quantities supplied by all the firms producing variety i, that is, the licensor and her licensees, and the second summation is across quantities supplied by all the firms producing variety j. Implicit in the above demand function is the absence of intragroup differentiation: the licensees produce exactly the same variety as their licensor. Note that for $k_i = k_j = 0$ the two demand functions coincide. Hence, to understand how the outcomes under veto power and no veto power differ from the benchmark case, we need to determine the licensing activity generated by a joint patent under each regime in three different situations: collusion, deviation from collusion and competition.

3.2.1 Licensing Activity and Product-Market Profits

Suppose first that the incumbents *compete* in the product market. The profit maximization problem of a product-market competitor producing variety i is given by

$$\max_{q_i}\{a - q_i - \sum_{k_i} q_r - \mu \sum_{k_j+1} q_s\}q_i$$

Taking the first order condition with respect to q_i and imposing in-group symmetry, we get the equilibrium quantity q_i^n set by each product-market competitor producing variety i which is

$$q_i^n(k_i, k_j) = \frac{a\,(2 + k_j - \mu(k_j + 1))}{(k_i + 2)(k_j + 2) - \mu^2(k_i + 1)(k_j + 1)}$$

The product-market profit of each firm producing variety i is then $v_i^n(k_i, k_j) = (q_i^n)^2$. The incumbent i's total equilibrium profit can be expressed as a function of that profit, that is, $\pi_i^{jp}(k_i, k_j) = (k_i + 1)v_i^n$.

In a regime *without veto power*, each incumbent i chooses k_i to maximize its total profit. The first-order condition of profit maximization is expressed as

$$v_i^n(k_i, k_j) + k_i \frac{\partial v_i^n(k_i, k_j)}{\partial k_i} = 0.$$

The second-order condition can be shown to be satisfied at any interior equilibrium.[8] Intuitively, licensing has two opposing effects on the total profits of an incumbent. First, by selling an additional license, the incumbent captures more market share. The rents earned by the licensee fully accrue to the incumbent in the form of licensing payments $v_i^n(k_i, k_j) > 0$. Second, licensing intensifies competition, and the incumbent experiences erosion of profits in her own business, that is, $\partial v_i^n(k_i, k_j)/\partial k_i < 0$ due to an additional competitor in the product market. These losses are, however, shared with the other incumbent such that the licensor does not fully internalize the reduction in industry profits. The relative strength of these two effects crucially depend on the degree of product differentiation. If the incumbents are close competitors producing fairly homogenous goods, the profit erosion felt by one incumbent due to an additional license sold by the other incumbent is strong. Imposing symmetry ($k_i = k_j = k^n$) and solving the first-order condition for the equilibrium number of licenses k^n yields

$$k^n(\mu) = \frac{1}{\sqrt{1 - \mu^2}} - 1. \tag{3}$$

From the above expression it is obvious that the equilibrium quantity of licenses sold increases with the substitutability of the products. When the products are perfectly differentiated (independent), that is, $\mu = 0$, no licensing occurs in equilibrium, and profits are the same as in the benchmark case. For $\mu > 0$, incumbents both sell a positive number of licenses in equilibrium which increases when the products become more homogenous.[9] The incumbents would, however, benefit from restricting their licensing activity. Taking the derivative of an incumbent's equilibrium profit function with respect to k^n shows that licensing lowers the incumbent's product-market

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[8]Using the first order condition, the second order condition can be written as $\partial^2 \pi_i^{jp}(k_i, k_j)/\partial k_i^2 = 1/2 \partial \pi_i^{jp}(k_i, k_j)/\partial k_i < 0$.

[9]This result still holds in the presence of transaction costs as long as they are sufficiently small.

profit:

$$\frac{\partial \pi^{jp}(k^n)}{\partial k^n} = q^n(k^n)\left(q^n(k^n) + 2(k^n+1)\frac{\partial q^n(k^n)}{\partial k^n}\right) = \frac{-a^2\left(k^n(1+\mu)+\mu\right)}{(k^n+2+\mu(k^n+1))^3} < 0.$$

In a regime *with veto power*, an incumbent vetoes the rival's decision to license the jointly-patented technology if this negatively affects her product-market profit. The partial derivative of incumbent i's total profit with respect to k_j is

$$\frac{\partial \pi_i^{jp}(k_i, k_j)}{\partial k_j} = 2(k_i+1)q_i^n(k_i, k_j)\frac{\partial q_i^n(k_i, k_j)}{\partial k_j} < 0,$$

and thus, each individual decision to license is vetoed by the co-assignee. As a consequence, the incumbents do not sell any licenses in equilibrium, and profits are the same as in the benchmark case.

Suppose now that, when *colluding*, the incumbents can implement the joint profit maximizing outcome. It is straightforward that joint profit maximization cannot involve any licensing. The intuition is simple: due to the efficiency effect which captures the negative relationship between aggregate industry profits and the number of producers (Tirole, 1988), an incumbent cannot increase profits by licensing out the production of the joint profit maximizing quantity to market entrants. Hence, collusion in both the veto power and the no veto power regimes does not involve any licensing. The collusive profits of incumbents that hold a joint patent are therefore no different from that in the benchmark case.

Finally, let us examine what happens when one incumbent *defects* from a collusive agreement by playing her best response to the collusive play of the rival. Again, due to the efficiency effect, a deviating incumbent cannot gain by licensing out the best response quantity to market entrants. To see this, denote $BR_i(q_j^c) \equiv q_i^d$ and suppose that firm i deviates from the collusive agreement and plays its best response while j sticks to the collusive quantity q_j^c and no licensing. The profit maximization problem of a product-market competitor producing variety i, i.e. the licensor and its licensees, is given by

$$\max_{q_i^d}\{a - q_i^d - \sum_{k_i} q_r - \mu q_j^c\}q_i^d$$

Taking the first-order condition and imposing in-group symmetry yields the best-response profits of incumbent i

$$\pi_i^{jp}(k_i, q_j^c, k_j^c) = (k_i+1)\left(\frac{a - \mu q_j^c}{k_i+2}\right)^2.$$

As $\partial \pi_i^{jp}(k_i, q_j^c, k_j^c)/\partial k_i < 0$, the best response to the collusive play of the rival involves no licensing. Hence, the optimal deviation in both the veto power and the no veto-power regimes involves no licensing, and the defection profits when incumbents hold a joint patent are thus identical to the defection profits in the benchmark case.

3.2.2 Collusive Incentives

The above analysis has shown that a joint patent lowers product-market profits of competing incumbents in the absence of veto power unless the products are perfectly differentiated. Hence, according to that logic, competing incumbents should avoid filing a joint patent in a one-shot interaction. However, if they interact repeatedly in a long-term relationship, lower Nash profits may help to sustain collusion: harsher punishment in case of a unilateral breach of the collusive agreement increases the losses from retaliation and thus serves as an additional threat. Compared to veto power and the benchmark case, collusion is then easier to sustain in the absence of veto power. This result is reminiscent of what the literature in industrial economics has labeled "hostages' exchange" (see Ayres (1987), Krattenmaker and Salop (1986) and Williamson (1983)).

Denote the critical discount factors above which the collusive strategy profile can be sustained with a joint patent under a veto-power and a no veto-power regime by $\widetilde{\delta}_v^{jp}$ and $\widetilde{\delta}_{nv}^{jp}$ respectively. Our analysis then implies that

$$\pi_i^{jp}(q^n, k^n) \leq \pi_i(q^n) \;\Rightarrow\; \widetilde{\delta}_{nv}^{jp} \leq \widetilde{\delta}_v^{jp} = \widetilde{\delta}$$

for $\mu \in [0, 1]$ and strictly so if $\mu > 0$.

To derive an empirically testable prediction on whether joint patents serve as a collusive device in a regime without veto power such as the US, we consider the effect of a change in the substitutability parameter μ on the ease of collusion. From the expression for the equilibrium number of licenses in (3) we know that increasing the substitutability of products enhances licensing and thus intensifies product-market competition and decreases product-market profits. Additional to this indirect effect via licensing, increasing μ has a negative direct effect on equilibrium profits. Moreover, less differentiation lowers profits from collusion as well as from a deviation. Whether less differentiation raises or lowers the critical discount factor depends on the relative strength of these effects. Figure 1 displays the critical discount factors without veto power, $\widetilde{\delta}_{nv}^{jp}$, and veto power, equal to the one of the benchmark case, $\widetilde{\delta}$ as a function of μ. In the absence of a joint patent, or with veto power, more homogenous products make collusion slightly more difficult, whereas it becomes easier

with a joint patent under a regime without veto power. Intuitively, the more homogenous the products, the tougher is quantity competition in the static equilibrium and thus, the harsher is the retaliation following a deviation. This effect as well as lower profits from a unilateral deviation make collusion easier. At the same time, however, the collusive profits decrease which makes collusion harder. Without a joint patent and with a joint patent under a regime with veto power the third effect dominates. In the absence of veto power, however, higher substitutability raises the number of licenses sold in the competitive equilibrium, and profits on the punishment path decrease drastically such that the the first two effects outweigh the third one. As a consequence, collusion becomes easier in that case.
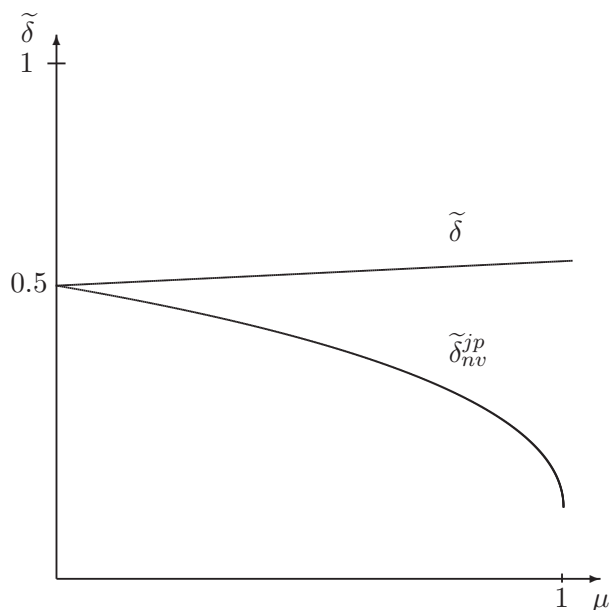

Figure 1: Collusive Thresholds

We have shown that when incumbents compete in the product market under a regime without veto power they should have little incentives to file a joint patent. Moreover, compared to a regime with veto power, these incentives should, if anything, decrease with the substitutability of the products. If, however, joint patents help product-market collusion, the more homogenous the products, the stronger the incumbents' incentives to choose joint ownership in a regime without veto power. We can thus formulate our first testable hypothesis:

Hypothesis 1 *In the absence of veto power and if a joint patent serves collusive purposes, firms engaged in a RJV are more likely to file a joint patent the closer they are in the product market.*

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3.3 Licensing Behavior

Our first hypothesis conjectures that a high propensity to file joint patents in a regime without veto power when competitors are close hints at collusion in the product market. However, in principle, one could argue that there are factors other than collusion which we do not observe and that may drive the effect in Hypothesis 1. For example, the occurrence of joint patents is positively related to joint invention at the innovation stage. Technology overlap between inventors may enhance the creation of joint knowledge because it is easier for them to learn from each other (Lane and Lubatkin, 1998). Hence, one could argue that firms that are closer in the product market have a greater technological overlap and are thus prone to producing joint inventions and joint patents (Kim and Song, 2007). Belderbos et al. (2012) show that joint patents between product-market competitors obtain more forward citations than other co-assigned patents which suggests that they protect more valuable innovations. They argue that joint patents not only mitigate ex-ante knowledge appropriation concerns, but they also sustain mutual relational trust. All this suggests that innovators' incentives to file a joint patent would increase with their product-market closeness without any collusion involved.

One way of verifying whether the positive correlation between product-market proximity and firms' propensity to co-assign a patent reflects a collusive use of joint patents is to examine licensing behavior of the co-assignees. Our discussion in Section 3.2 implies that if factors other than collusion play a role in co-assigning a patent, joint patents are associated with greater licensing activity in a regime without than in regime with veto power compared to single-owned patents (unless the products are perfectly differentiated). Moreover, without veto power, the licensors sell more licenses for co-assigned patents when they are closer competitors as the incentives to (over)licensing increase in more homogenous product markets. We can thus formulate our second theoretical prediction:

Hypothesis 2 *If joint patents do not serve collusive purposes, they are associated with greater licensing activity relative to single-owned patents in a regime without than in a regime with veto power. In addition, given a joint patent, licensing activity increases the closer the co-assignees are in the product market.*

4 Data

The data used to empirically validate our theoretical predictions cover the periods 2000-2004 for the US and 2000-2006 for European firms and consist of three

components: 1) firm-level information, 2) patent data, and 3) data on RJVs and licensing.

4.1   US Data

The firm-level data for the US come from WRDS Compustat North America. Compustat contains data on companies traded in the US stock market. Given the objective of our analysis, we limit the data to US firms that report a US address, which leaves us with about 11,650 US firms for the period 2000-2004.

We use the patent data from the NBER Patent data project which links USPTO patent information to Compustat data (Hall et al., 2001; Cockburn et al., 2009). We match the NBER data with our Compustat files. We complement the Compustat data with information from Dlugosz et al. (2004) to allocate firms into business groups. This information in combination with the dynamic patent assignment information provided by the NBER Patent data project allows us to distinguish patents jointly held within business groups from patents jointly held by legally independent companies.[10]

4.2   European Data

The firm-level data for Europe come from Bureau van Dijk's Amadeus database. We limit our analysis to 4 countries that are part of the European Union plus Switzerland.[11] We use the data for the seven-year period 2000-2006. Since firms that exit are dropped from the database after four years, we use two versions of Amadeus (October 2002 and 2005) to ensure that our sample is not a selection of surviving companies. We use the ownership information available in Amadeus to allocate firms into business groups. Since each version of the Amadeus data provides only a snapshot of firms' ownership structure at that point in time, we construct our ownership links using a different Amadeus version for each year covered by our sample. This means that we are able to track changes in firms' ownership structure over time and thus to distinguish patents held jointly by firms within the same business group from joint patents held by legally independent companies. This turns out to be empirically much more important in the case of European firms than for the US.[12]

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[10]We also check the data manually to filter patents that are co-assigned among members of the same business group.

[11]The countries are: France, Germany, Netherlands, United Kingdom, and Switzerland.

[12]Again, we also check the data manually to filter patents that are co-assigned among members of the same business group.

The second component consists of patent data which come from the European Patent Office (EPO) Worldwide Patent Statistical Database (PATSTAT).[13] We include in our analysis patents published both by the EPO, that is patents that go through the European Patent Convention (EPC) channel, and patents filed directly with national patents offices. This includes patents that were applied for at WIPO via the Patent Cooperation Treaty (PCT) and designated the EPO or directly national patent offices. Due to the lack of unique firm identifiers in the patent data, we matched the patent data to Amadeus using firms' names.[14]

4.3 RJV and licensing data

The third component consists of information on RJVs and licensing. We extract basic information on RJVs and licensing contracts from the Thomson Reuters SDC Platinum database for the period 2000-2008. We retain only contracts that involve at least one US and/or European company which leaves us with about 3,000 RJVs and 2,500 licensing contracts. Thomson Reuters assembles the data on RJVs and licensing contracts from publicly available information, such as trade journals and the national and international business press. The data on RJVs and licensing contain basic information on the firms participating (e.g. firm names, country, SIC code) as well as on the subject of the RJV/licensing contract (e.g., date signed, content description, SIC code). The licensing data also allow us to distinguish exclusive and cross-licensing deals from 'standard' licensing contracts. We matched the SDC Platinum RJV and licensing data manually to Amadeus and Compustat. Given the large-firm bias of SDC Platinum which has been documented in Anand and Khanna (2000), we complemented the data on licensing contracts with information obtained from the ktMINE database.[15] ktMINE provided us with 11,189 licensing agreements including 15,187 parties, which we matched manually to Amadeus and Compustat.

5 Empirical evidence

In this section, we show descriptive empirical evidence to validate the hypotheses developed in Section 3 above. The first part of our analysis is concerned only with

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[13]We use the Patstat version October 2011.

[14]For detailed information on the matching procedure see Helmers et al. (2011).

[15]We selected ktMINE after reviewing all commercial and non-commercial providers of licensing data and evaluating the option of collecting licensing data from news sources ourselves. According to our market research, ktMINE offers the most comprehensive database. For more information see http://www.ktmine.com

firms' propensity to file jointly for a patent whereas the second part looks at firms' licensing behavior conditional on the type of patent (joint or individually-owned) that they have chosen.

5.1 Descriptive evidence

Table 1 shows aggregate descriptive statistics on firms' patent filings.[16] The first three columns show the absolute number of firms that patent individually and that file joint patents as well as the share of firms that hold at least one joint patent. The most important insight from Table 1 is the substantial difference between the US and Europe both in terms of the share of firms that hold at least 1 joint patent and the share in total patent filings accounted for by joint patents. About 13 percent of European firms filed at least 1 patent together with another legally independent company, whereas this share is almost 20 percent in the US. In contrast, in terms of the absolute number of patent filings (shown in Columns 4-5), less than 1.5 percent of total filings by US companies are joint patents. This share is much larger in Europe (almost 4 percent).[17] In light of the absence of veto power in the US legal regime, we would expect to see a considerably lower share of filings to be jointly owned by companies. Yet, the large share of patenting US companies that file a non-negligible number of joint patents (about 2,200 granted patents) is intriguing.

Table 2 looks at the distribution of patents – both individually and jointly owned – across sectors. Again, there are important differences between the US and Europe in terms of filings of joint patents. In the US, most patenting firms are in the chemical and pharmaceutical industry, as well as in electronics and communication equipment as well as optical and medical instruments. These are also the industries with the largest share of companies that hold co-assigned patents. In particular chemicals and pharmaceuticals stand out with a share of almost 40 percent (shares are computed as the ratio of the number of firms with a co-assigned patent and the number of patenting firms). But also the shares of 17 and 10 percent

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[16]Note that we drop a range of sectors in which firms tend not to rely on patents, including agriculture, financial services, insurance, real estate, etc. See Table 2 for a sector breakdown.

[17]The share of jointly held patents shown in Table 1 is considerably lower than the share of about 15 percent of EPC patent applications by French manufacturing firms found by Duguet (1994) for the period 1980-1989. The large share of joint patents found by Duguet may be in part explained by the fact that he does not correct for joint patents held by different firms within business groups. Hicks and Narin (2001) attempt to correct for any such potential bias by removing patents that are jointly owned by parent companies. While Hicks and Narin (2001) also include patents held by public institutions, they find a slightly lower share of joint patents among all US patents: between .2 percent in 1980 and 1.3 percent in 1999. Hagedoorn (2003) finds a similar share of 1.3 percent of US patents to be jointly owned by companies that do not share the same parent company during the period 1989-1998.

in electronics and communication equipment and optical and medical instruments, respectively, are noteworthy.[18] When we look at the share of joint patents among total filings, as already shown in Table 1, the share of joint patents is considerably lower than the share of jointly patenting companies among all patenting companies. Here, only chemicals and pharmaceuticals stand out with a share of around 4.4 percent of co-assigned patents in total filings. Joint patents are much more widely distributed across sectors among European firms. In Europe, the share of patenting companies is largest in the machinery and engines as well as electronics industries along with business and engineering services. Table 2 shows that these sectors also have the largest share of companies that have co-assigned patents. Also chemicals and pharmaceuticals has a high share of almost 7 percent. When we look at the share of joint patents in total filings, we see that the electrical machinery industry stands out, with a share of almost 11 percent. Most other industries have shares of around 3-5 percent. As expected, based on the evidence shown in Table 1, these shares are much larger in Europe than the US, which reflects a more intensive use of joint patents, inline with our theoretical discussion above about the ability to veto licensing of co-assigned patents.

Finally, Figure 2 looks directly at joint patenting behavior and product market proximity. We plot the share of joint patents that are filed by firms within industries, where we distinguish between industries at the SIC 2-digit and 3-digit level. That is, we divide the number of patents jointly held by firm i and firm j with i and j operating in the same 2- or 3-digit industry s by the total number of joint patents. The figure shows that in the US, joint patents are much more frequently held by direct product-market competitors than in Europe. Yet, there is still a substantial amount of co-assignment between direct product-market competitors in Europe, which hints at co-assignment being the outcome of joint research, which may be more likely between companies that operate in the same product market.

5.2 Propensity to file a joint patent

We start by looking at the relation between product-market competition and the probability of filing a joint patent. Our objective is to test whether firms are more likely to file a joint patent if they are close competitors in the product market. According to our theoretical analysis, this positive relationship between the propensity to file a joint patent and proximity in the product market should be more pronounced in the US than in Europe.

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[18]Previous findings also indicated that joint patents are relatively frequent in the information technology and instrumentation industries (Hagedoorn, 2003).

To test Hypothesis 1, we need to construct a measure of proximity in terms of product-market competition between firms. We resort to a simple measure of proximity by looking at the SIC codes that companies report. We consider firms to be close product-market competitors if they operate in the same 3-digit industry.[19] We then estimate the probability that firms i and j file for a joint patent conditional on patenting using the following dyadic specification:

$$Prob(J_{ijt}|P_{it}) = \alpha + \mu|D_{ij}| + \beta_1|X_{it} - X_{jt}| + \beta_2(X_{it} + X_{jt}) + \theta_t + \varepsilon_{ijt} \qquad (4)$$

where $Prob(J_{ijt}|P_{it})$ denotes the probability that firms i and j file for a joint patent J_{ijt} conditional on having applied for a patent. This means we limit the set to firms that file for a patent in the same year t. The specification described in Equation (4) also means that we count only joint patents between companies included in our dataset. D_{ij} denotes the distance between firms i and j in the product market as measured by firms' 3-digit SIC codes. This measure is time-invariant. X_{it} and X_{jt} denote firm-level characteristics which enter symmetrically in the dyadic specification.[20] We include the number of RJVs firms are engaged in, firm-size measured as the log of total assets to account for firms' potential tendency to collude with larger rivals as well as a firm's total number of patent filings among the time-varying company characteristics. Table 3 contains descriptive statistics. We also include a time trend.[21]

Table 4 reports the corresponding OLS results where we estimate separate models for the US and Europe.[22] The main parameter of interest is μ, which turns out to be positive and statistically significant in both the US and Europe. This means we find proximity in the product market to be positively correlated with the propensity to file a joint patent (conditional on patenting) regardless of the existence of veto power. In the US, competing in the same 3-digit SIC industry increases the propensity to file for a patent jointly by 1.6 percent, in Europe by 0.9 percent. To investigate this further, we interact the product market proximity measure with industry-specific

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[19]For example, we distinguish within the 2-digit 'Industrial And Commercial Machinery And Computer Equipment' industry between nine 3-digit sub-sectors including for example 'Computer And Office Equipment' or 'General Industrial Machinery And Equipment.'

[20]Note that in our set-up, dyadic links are undirected.

[21]Standard errors are clustered at the dyad-level to account for the twoway-correlation induced by the dyadic structure of the data.

[22]We restrict the data to firms that report at least one joint patent in a given year. If we included all patenting companies regardless of whether they ever obtained a joint patent, estimating the dyadic specification in Equation (4) would be computationally infeasible.

dummies, where industries are broadly defined.[23] These dummies indicate that firms i and j belong to the same broadly-defined industry and can thus be interpreted as dyad-level specific effects. Columns (II) and (VI) look at the chemicals and pharmaceutical industries in Europe and the US. While the industry dummy variable is not statistically significant in Europe, it is negative and statistically significant in the US. This means, within the chemicals and pharmaceuticals industry, firms are less likely to file for a patent jointly. The same is true for the electronics industry (Columns (IV) and (VIII)). In contrast, in the motor vehicles industry, firms in the same sector are more likely to file for a patent jointly (Column (III) and (VII)). This provides some evidence for heterogeneity in the relationship between product-market proximity and joint patenting behavior across industries. That is, although overall product-market proximity is positively correlated with the propensity to file for a joint patent, in some industries companies are less likely to co-assign patents among product-market competitors in the absence of a veto right, which is inline with our theoretical model.

5.3 Licensing activity

Our theoretical discussion implies that if joint patents do *not* serve a collusive function, we should observe a higher likelihood of granting a license on a joint patent relative to an individually-owned patent. And if a company has filed a joint patent, this negative correlation between co-assigning a patent and licensing should be more pronounced the closer the co-assignees compete in the product market.

Our main empirical challenge in this context is the absence of a direct link between a patent and the corresponding license. That is, the available licensing data do not reveal the patent on which the licensing contract is based. Especially for larger companies this imperfect mapping between patents and licenses may be problematic as firms typically file for several joint patents and issue a number of licensing contracts. For this reason, we regard the evidence provided in this section as descriptive and look for a broad pattern in the data on the correlation between joint patents and licensing behavior.

To test our second theoretical prediction, we estimate the following model

$$(L_{it}|P_{it-1}) = \alpha + \mu JP_{it} + \beta X_{it} + \theta_t + \varepsilon_{it} \tag{5}$$

where $L_{it}|P_{t-1}$ denotes the number of licenses (L_{it}) granted by firm i in year t conditional on the firm having obtained a patent P_{it-1} in a previous period. The

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[23]For example, Pharma/Chemicals contains 10 3-digit SIC codes (280-287, 289, 385).

main conditioning variable of interest is JP_{it} which is equal to one if the firm applied for a joint patent and zero otherwise. X_{it} contains some firm-level observable characteristics that are correlated with a company's propensity to license, notably the number of RJVs the firm engaged in, firm size measured as the log of total employees, and the total number of the company's patent filings. Table 3 contains descriptive statistics.

In addition to Equation (5), we also estimate a model where we limit the underlying data to companies that have obtained a joint patent and ask whether companies that have co-assigned patents with close product-market competitors are less likely to license. That is we estimate

$$(L_{it}|J_{it-1}) = \alpha + \delta|\frac{\sum_{i \neq j}^{N} D_{ij}}{N}| + \beta X_{it} + \theta_t + \varepsilon_{it} \tag{6}$$

where $|\frac{\sum_{i \neq j}^{N} D_{ij}}{N}|$ denotes the average distance in the product market between firm i and the co-assignees of its joint patent j. As in Equation (5), X_{it} denotes time-varying company characteristics. θ_t denotes a time trend.

Table 5 reports the corresponding OLS results from estimating Equations (5) and (6) above (Columns (I), (II), (V), and (VI) correspond to Equation (5), whereas Columns (III), (IV), (VII), (VIII) correspond to Equation (6)). The table shows that in the case of the US, sharing the ownership of a patent is associated with significantly less licensing. For Europe, in contrast, we do not find a statistically significant correlation. When we look at the relation between product-market proximity and licensing (conditional on the firm having co-assigned a patent), that is Equation (6), we also find a negative, albeit not statistically significant, correlation for the US. In the case of European firms, the coefficients on product market proximity are positive, but not statistically significant. Hence, these descriptive results suggest a negative correlation between licensing and joint patenting as well as product-market competition, for the US.

6 Conclusion

In this paper, we suggest one potential reason behind the empirically observed co-assignment of patents between product-market competitors and show potential implications for competition in the product and technology markets. Although joint patents are relatively rare, our analysis shows that they deserve attention mainly for two reasons: first, joint patents might affect the behavior of companies in the technology market and thus change their incentives to license out their technology;

second, joint patents might help sustain collusion in the product market and thus require closer scrutiny by antitrust authorities.

Our theoretical model shows that when joint patents allow co-assignees to freely dispose of their intellectual property (as is the case in the US), they have incentives to over-license. This occurs because each licensor does not take into account the negative externality that licensing generates on the profits of the co-assignees. This negative externality is greater the closer the co-assignees are in the product space, which implies over-licensing is more likely when the firms compete in the same market. Thus, from this perspective, joint patents are less attractive if firms are direct competitors.

We show that because joint patents lead to over-licensing and over-licensing implies lower profits in equilibrium, joint patents can help sustain collusion in the product market. Indeed, holding a joint patent lowers the Nash equilibrium profits that a breaching firm can earn in the product market after collusion has broken down and thus makes a deviation from the collusive agreement more costly. We show that this is more likely the closer the co-assignees are in the product market. Thus, our model predicts that the closer the firms are in the product space, the more likely it is that their joint patents serve collusive purposes. Our model also suggests that if joint patents serve a collusive function, they should be associated with less licensing activity than single-owned patents. The combination of these two theoretical predictions suggests that if firms are close competitors in the product market, they nevertheless hold joint patents, and little licensing occurs by these companies, the joint patents may serve collusive purposes.

We provide evidence by drawing on a large dataset that contains information at the firm-level about patents, joint patents, RJVs and licensing for a large number of US and European companies. A comparison of the joint patenting and licensing behavior of US and European companies is useful in our context because co-assignees can veto the licensing of co-assigned patents in Europe, whereas they do not have such a veto right in the US. We offer some descriptive evidence on the differences between the US and Europe that are consistent with the different legal treatment of joint patents in the two jurisdictions. Our empirical findings are consistent with the collusive hypothesis in the US, that is, joint patents might be motivated by collusive purposes in the US. This finding has potentially important implications for competition policy. Also, because joint patents are often the outcome of RJVs, which have been shown to have collusive potential (Goeree and Helland, 2009), our analysis offers an additional angle through which companies that engage in collusive practices through RJVs can sustain a collusive agreement. Our data also supports

the theoretical prediction that when joint patents are motivated by collusive purposes, they are associated with fewer licenses than single-owned patents. This could have important consequences for the diffusion of technology and the functioning of technology markets more generally.

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Figure 2: Product market competition and joint patenting
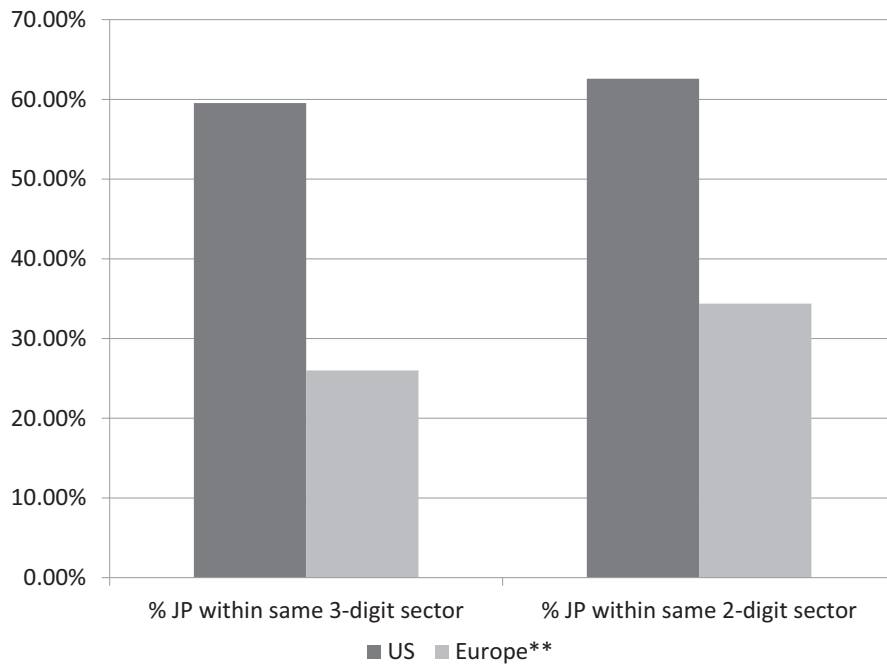
Notes: ** Includes France, Germany, Netherlands, Switzerland, United Kingdom.

Table 1: Individually-owned and Joint Patents – US vs Europe

Year	# Firms holding ≥ 1 Patent† (I)	# Firms holding ≥ 1 Joint Patent◇ (II)	% Firms holding ≥ 1 Joint Patent (III)	# Patents (IV)	# Joint Patents (V)	% Joint Patents (VI)
US						
2000	1,272	198	15.57%	40,206	727	1.81%
2001	1,263	170	13.46%	39,199	521	1.33%
2002	1,155	142	12.29%	34,993	482	1.38%
2003	1,004	107	10.66%	24,627	342	1.39%
2004	721	58	8.04%	11,993	120	1.00%
Total	1,763	341	19.34%	151,018	2,192	1.45%
Europe♭						
2000	2,772	347	12.52%	24,996	862	3.45%
2001	2,731	331	12.12%	23,596	996	4.22%
2002	3,039	368	12.11%	27,261	1,124	4.12%
2003	3,351	355	10.59%	29,410	1,050	3.57%
2004	3,221	354	10.99%	27,368	1,107	4.04%
2005	3,826	353	9.23%	27,844	1,157	4.16%
2006	3,804	310	8.15%	26,497	1,100	4.15%
Total	12,596	1,658	13.16%	186,972	7,396	3.96%

Notes: † US: USPTO filings; Europe: National and EPO filings;
◇ Excludes patents jointly held by members of same business group;
♭ Includes France, Germany, Netherlands, Switzerland, United Kingdom.

Table 2: Joint Patents by sector – US vs Europe

Year	% Firms holding ≥ 1 Patent[†]		% Firms holding ≥ 1 Joint Patent[◇]		% Joint Patents of Total Filings	
	EU	**US**	**EU**	**US**	**EU**	**US**
Food & tobacco	1.72	1.99	1.39	2.05	3.33	1.07
Textiles, apparel & footwear	2	1.47	1.87	0.29	6.28	1.34
Lumber & wood products	0.87	0.28	0.3	0.00	3.06	0.00
Furniture	0.92	0.85	0.48	0.88	2.13	0.80
Paper & paper products	2.26	1.36	2.41	1.17	6.94	0.34
Printing & publishing	2.42	0.74	2.59	0	5.48	0.00
Chemical/Pharma products	5.48	21.33	6.82	39.88	5.40	4.41
Plastics & rubber prods	4.83	1.53	5.43	1.47	5.08	1.06
Stone, clay & glass	1.87	0.62	1.75	0.59	3.11	1.17
Primary metal products	1.9	1.36	2.35	0.88	3.88	1.15
Fabricated metal products	9.36	1.87	8.81	0.88	3.82	0.65
Machinery & engines	12.92	5.16	10.19	6.16	1.64	1.01
Computers & comp. equip.	0.72	4.88	0.9	5.28	3.05	0.45
Electrical machinery	2.75	3.35	2.05	1.76	10.87	0.38
Electronic inst. & comm. eq.	8.68	16.39	8.32	17.01	1.83	1.06
Transportation equipment	0.9	1.42	1.51	2.05	3.05	0.80
Motor vehicles	2.59	2.04	3.26	2.05	2.27	1.73
Optical & medical instruments	2.78	15.31	1.93	10.26	1.71	0.92
Misc. manufacturing	3.87	1.64	4.22	0.88	7.31	0.46
Computing software	6.08	12.71	6.09	4.4	7.39	1.43
Business services	10.62	1.53	14.84	0	5.58	0.00
Engineering services	14.47	2.16	12.48	2.05	3.64	4.19

Notes: † US: USPTO filings; Europe: National and EPO filings;
◇ Excludes patents jointly held by members of same business group, shares computed as # firms
with joint patents divided by # patenting firms;
♭ Includes France, Germany, Netherlands, Switzerland, United Kingdom.

Table 3: Descriptive statistics – US vs Europe

Year	EU		US	
	Mean	Std. dev.	Mean	Std. dev.
Patent propensity sample				
# Joint Patents	3.40	19.73	3.64	7.98
# Patents	51.07	221.91	205.34	444.68
# RJVs	0.05	0.42	0.32	0.92
Total assets (000 EUR/US$)	1,474	6,542	18,998	55,564
# Employees	6,372	23,312	38,249	70,858
Licensing activity sample				
# Licenses	0.01	0.13	0.34	1.00
Joint Patent (0/1)	0.26	0.44	0.39	0.48
# Patents	15.27	107.20	77.96	247.09
# RJVs	0.02	0.25	0.16	0.66
Total assets (000 EUR/US$)	635.15	3,721	7,719	29,679
# Employees	2,056	11,120	18,959	43,830

Table 4: Propensity to file joint patent (dyadic OLS regression results)

Dep. Var. Joint Patent (0/1)		**Europe**[b]				US			
		(I) All	(II) Pharma/Chemicals	(III) Motor Vehicles	(IV) Electronics	(V) All	(VI) Pharma/Chemicals	(VII) Motor Vehicles	(VIII) Electronics
Product market proximity (PMP) (0/1)ℜ		0.009***	0.008***	0.008***	0.010***	0.016***	0.014*	0.015***	0.016***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.007)	(0.004)	(0.004)
Industry (0/1)‡			-0.0003	-0.0001	-0.0008***		-0.002***	0.086*	-0.001***
			(0.0005)	(0.0005)	(0.000)		(0.000)	(0.051)	(0.000)
PMP × Industry			0.008	0.011*	-0.009***		0.004	-0.009	0.001
			(0.007)	(0.006)	(0.006)		(0.007)	(0.080)	(0.012)
# RJVs	Difference	0.002	0.002	0.002	0.002	-0.001	-0.001	-0.001	-0.001
		(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.005)	(0.005)
	Sum	-0.0006	-0.0006	-0.0007	0.0006	0.0006	0.0005	0.0009	0.0005
		(0.001)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.004)	(0.004)
Company size (log assets)	Difference	0.00003	0.00004	0.00004	0.00002	0.001	0.001	0.001	0.001
		(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0006)	(0.005)	(0.0005)	(0.0005)
	Sum	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	0.0006	0.0002	0.0005
		(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0006)	(0.0007)	(0.0006)	(0.0006)
Total patent filings	Difference	-0.002***	-0.002***	-0.002***	-0.002***	-0.002	-0.002	-0.002	-0.002
		(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.001)	(0.001)	(0.001)	(0.001)
	Sum	0.002***	0.002***	0.002***	0.002***	0.002	0.002	0.002	0.002
		(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.002)	(0.002)	(0.002)	(0.002)
Year Dummies		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. obs.		403,473	403,473	403,473	403,473	17,920	17,920	17,920	17,920

Notes: b Includes France, Germany, Netherlands, Switzerland, United Kingdom.
ℜ PMP=1 if firms i and j are in the same SIC-3 digit industry.
‡ Industry describes broad industries (i) Pharma/Chemicals, (ii) Motor Vehicles, and (iii) Electronics which contain several 3-digit industries. Industry = 1 if firms i and j are in the same broad industry.
Robust standard errors clustered at the dyad-level.

Table 5: Licensing Activity (OLS regression results)

Dep. Var. # Licenses	Europe				US			
	# Firms holding ≥1 Patent (I)	# Firms holding ≥1 Patent (II)	# Firms holding ≥1 Joint Patent (III)	# Firms holding ≥1 Joint Patent (IV)	# Firms holding ≥1 Patent (V)	# Firms holding ≥1 Patent (VI)	# Firms holding ≥1 Joint Patent (VII)	# Firms holding ≥1 Joint Patent (VIII)
Joint Patent (0/1)	-0.004 (0.004)	-0.004 (0.004)			-0.102* (0.053)	-0.103** (0.051)		
PMP (0/1)ℜ			0.029 (0.028)	0.025 (0.028)			-0.502 (0.379)	-0.397 (0.381)
# RJVs		0.050* (0.027)		0.052 (0.036)		0.280*** (0.061)		0.307*** (0.075)
Company size (log employment)	-0.001 (0.002)	-0.001 (0.001)	-0.002 (0.003)	-0.002 (0.002)	0.011 (0.020)	0.007 (0.020)	-0.054 (0.065)	-0.059 (0.064)
Total patent filings	0.002* (0.001)	0.002* (0.001)	0.001 (0.004)	0.001 (0.003)	0.010 (0.014)	0.012 (0.014)	0.041 (0.051)	0.048 (0.051)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. obs.	35,549	35,549	5,405	5,405	7,712	7,712	1,579	1,579

Notes: ♭ Includes France, Germany, Netherlands, Switzerland, United Kingdom.
ℜ Product Market Proximity PMP=1 if firms i and j are in the same SIC-3 digit industry.
Robust standard errors.