Licensing-In Technology Markets: How the Strength of Patents Influence Firm Strategies and Competition? Empirical Evidence from the 2004 Indian Patent Reforms

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Licensing-in technology markets: How the strength of patents influence firm strategies and competition? Empirical evidence from the 2004 Indian Patent Reforms

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ABSTRACT

The TRIPs mandate that seeks to harmonize patent laws the world over has been heavily debated especially by developing countries on the basis that stronger patents are likely to increase market concentration and prices. Contrary to this notion, using the recently initiated patent reforms in India, we show that stronger patents can actually increase competition. Building on the literature on Markets for Technology (MFT) we build model that identifies conditions under which stronger patents can actually stimulate competition as opposed to retarding it. We show that stronger patents increase entry by firms that do not have the ability to produce proprietary technology because stronger patents facilitate entry by in-licensing. On the other hand for firms, that do not have complementary capability but can generate proprietary technology, stronger patents makes it more attractive to out-license rather than entering product markets. Assuming that multinationals have high technical capability and relatively low complementary capability and that domestic firms have low technical and high complementary capability, we hypothesize that stronger patents should facilitate licensing between multinationals and domestic firms, especially to those that are incapable of producing proprietary technology. Our empirical results bear out the intuition that on an average, patenting activity increases with stronger patents and by more for multinationals relative to domestic firms and also by more in disembodied industries relative to embodied markets. Also, as a consequence we show that licensing activity and competition increases with stronger patents and by more in disembodied industries while licensing activity increases with stronger patents and by more in disembodied industries.

JEL codes: JEL - codes: L24, L50, L11

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Introduction

With the advent of International trade agreements such as TRIPS there has been a push towards harmonizing patent laws around the world. This has resulted in many emerging economics strengthening their IPRs in an effort to conform to the trade agreements. However, the influence of stronger IPRs on firm strategy, technological change and economic growth especially in the context on emerging economies is not well understood. In this paper we explore how stronger IPRs influence the rate of domestic inventive activity and multinational patenting activity using the recently implemented patent reforms in India.

The global push towards strengthening patent protection has been heavily debated. Much of the debate has been on the lines of "static losses" versus the "dynamic gains" from patenting. Opponents to the TRIPs mandate argue that stronger IPRs especially in emerging economies might just result in large "static losses" through transfer of rents to multinationals; since many emerging economy firms lag behind multinationals in technology capability, stronger patent laws may actually increase entry by multinationals into emerging markets which in turn may result in loses to domestic firms and increased profits to multinationals (Lanjouw, 1998; McCalman, 2001).

However, advocates of harmonizing patents laws the world over have argued in favor of the "dynamic gains" that might arise from stronger patent protection. This can occur in a variety of ways. First, by providing greater appropriability on inventions, stronger patent protection may in the long run stimulate domestic innovation. Second, stronger patent protection are likely to result in greater technology transfer by multinationals to their affiliates located in the country in which IPRs were hitherto weak mainly to produce products inefficiently. By doing so, the multinationals can use the freed up resources to enhance their innovative activity some of which may diffuse to other countries and enhance global welfare. Also, to the extent that there are spillovers from multinationals to domestic firms, strengthening patent protection should further increase innovation by domestic firms. Indeed, much of the focus in the literature has been on these aspects of how stronger patent protection may result in long term gains to the country undertook the change.

In this paper we focus on another dimension that has been relatively under explored in the literature. As Lanjouw (1998) notes yet another form of dynamic gains from stronger patent protection is that stronger IPRs stimulating vertical specialization which in turn enhances efficiency of R&D and production; it is plausible that stronger patent protection makes technology inputs cheaper and facilitates licensing activity. Building on the broader strategy literature that stronger IPRs decrease transaction costs involved in transferring knowledge (Teece, 1988; Arora, Fosfuri and Gambardella 2001), stronger IPRs

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should reduce transaction costs and should facilitate arm's length licensing. This in turn, should have should have two effects on firms strategies. First, multinationals or firms with superior technical capability that do not have complimentary capability to cater to local markets can exploit the existence of such markets and develop and license technology to others with superior complementary capability or to domestic firms. Therefore, stronger patent protection at the margin should encourage innovation and out-licensing especially by multinationals. In addition, stronger patent protection should facilitate greater entry by domestic firms. Stated otherwise, it should allow firms with inferior technical capability to in-license and enter product markets, which in the absence of strong patent protection would have been impossible. This is likely to result in higher competition and consumer welfare.

We take advantage of the recent patent reforms instituted in India to test our hypotheses. We compare how strengthening of patent reforms differentially affected the strategies of different types of firms in two types of industries –embodied vs. disembodied industries. To this end, we make use of a novel dataset that comprises of patents filed with the Indian Patent Office (Indian patents, henceforth) pre and post reforms that were enacted in the beginning of 2005.

This paper is organized as follows: the following section reviews literature and develops our hypotheses. We then briefly provide a background patenting in India along with a description of the data sources used in this paper which, is followed by our empirical analysis and findings. We conclude with a discussion of our findings.

Literature

Our main contribution is to highlight how strengthening patent protection in an emerging economy facilitates licensing between multinationals and domestic firms. Although much of the strategy literature extensively discusses how stronger IPRs facilitate licensing (Teece, 1986; Arora, Fosfuri and Ganbardella, 2001) as highlighted earlier, the role of stronger patent protection in facilitating exchange in technology between domestic firms and multinationals and thereby enhancing efficiencies in R&D and production has been under appreciated.

Much of early theoretical work in economics assumes an unambiguous relationship between the strength of patent protection and the rate of innovation. For instance Gilbert and Shapiro (1990), Kamien and Schwatz (1974) and Waterson (1990) show that stronger patent laws unambiguously increase the rate of innovation. Williams (1994) also substantiates this with his simulations and suggests that a 10% increase in patent term increases productivity by less 1/10th of 1 percent.

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Theoretically, there is a well-known tradeoff that is implicit while using patents to stimulate innovation. Stronger patent protection results in static losses and dynamic gains. The static losses from stronger patent protection arises from conferring upon firms higher (temporary) monopoly power which, comes at the cost of the consumers; since a monopolist faces a downward sloping demand curve she would set a price that is higher than the competitive price which is likely to lead to certain consumers forgoing consumption. Dynamic gains from stronger patent protection can arise in three ways.

First, by increasing appropriability of innovations, patents provide long term incentives to innovation. Hence patents in the long run might actually increase consumer surplus by increasing the number of products and services that are available for consumption. This aspect of dynamic gains from patenting has attracted significant empirical work in the literature. However, there appears to be a lack of consensus on whether stronger patent protection stimulates domestic R&D activity in the long run. Recently, Lerner (2009) examines 177 patent shifts across 60 countries spread across 150 years and finds that stronger patent do not stimulate domestic innovation. Rather surprisingly, he finds a negative impact on domestic innovation. Other empirical work too has found similar results. Sakakibara and Branstetter (2001) using Japanese patent reforms of 1988 empirically estimate the influence of expanded patenting scope on incentives to conduct R&D and find no clear evidence of stronger patent protection increasing R&D spends or innovative output. Jaffe (2000) and Kortum and Lerner (1998) point out that in the U.S., substantial increases in R&D spend occurred prior to reforms that strengthened patent protection. And hence the surge in patenting in the mid 1980's could have not been due to the changes in the patenting system in the U.S. On the contrary, Mansfield (1986) using survey data find that patent protection is important to stimulate R&D especially in industries such as pharmaceuticals and chemicals. Similarly, Evenson and Kumar (2001) and Chen and Puttitanum (2005) find positive effects of stronger IPR on domestic innovation. Qian (2007) provides empirical evidence that in part provides an answer to the mixed empirical evidence in the literature. She shows that that there is an optimal level of intellectual property rights regulation above which further enhancement reduces innovative activities. However, the theoretical reason for the inverted-U relationship between the strength of patent laws and its influence on domestic innovation is unclear.

A second source of potential dynamic gains from stronger patent protection arises from the fact that patents can help diffuse knowledge and can be a source of knowledge spillovers. Stronger patents provide incentives to disclose information, in exchange for temporary monopoly power (Nordhaus, 1969). Since all patents in theory must be written such that any person "skilled in the art" can make use of the information contained in the patent, more patents should increase spillovers and innovative output. Since stronger patent protection should increase patenting activity spillovers should increase as well. This view also finds very limited empirical support in the literature. Cohen et al., (2002) using a survey of Japanese and U.S firms finds that information spillovers from U.S patent applications are relatively low. Hall and Ziedonis (2001) too come to a similar conclusion. They find that in the semiconductor industry, firms that specialized in the design of chips increased their patent activity to protect their inventions after the establishment of the Central Courts of Appeals in the U.S. since many of these firms now had created incentives for inventors to use litigation as a means to extract royalties from prospective infringers. However, while this increased the total patenting activity in the industry, it was more on account of strategic patenting by large manufacturing firms to trade them in cross-licensing agreements, when threatened by infringement suits. Aoki and Spiegel (1998) show that the 1999 reform to the American Inventors Protection act that mandated that patent application be open to public inspection 18 months after the filing date, led to fewer innovations and patent applications. However, innovations in general after the policy change were more likely to be developed into products suggesting that knowledge diffusion was higher after the reform.

Yet another way in which stronger patent protection could result in dynamic gains is by stimulating vertical specialization which in turn enhances efficiency of both R&D and production. Since innovations face a revelation problem (Arrow, 1962) patent protection plays a key role in innovator's decision to license technology inputs (Green and Scotchmer, 1995; Merges, 1998; Arora and Merges, 2004). Strengthening patent protection establishes the inventor's bargaining power in licensing negotiations. As Gallini (2002) notes, with the exception of studies that probe the effects of The Bayh-Dole Act of 1980, how stronger patents simulates efficiencies in R&D and production has relatively been under explored in the literature. Gallini (2002), notes that by allowing universities to retain patent rights and offer exclusive licenses on inventions developed with federal funds, it essentially stimulated universities to out-license more. More generally, strong patents promotes MFT and greater vertical specialization (Arora, Fosfuri and Gambardella, 2001; Somaya and Teece, 2001). Stronger patent protection reduces transaction costs of negotiating contractual agreements. As a result, they encourage producers to in-license inputs such as technology inputs to manufacture the product rather than developing it by themselves. Although numerous industry studies have provided empirical evidence on how stronger patents encourages trade in technology, to our knowledge very papers have examined how stronger patents results in greater efficiencies in production and R&D at the country level. In this paper, using the recently implemented patent reforms in India as a context we show that strengthening patents in India stimulated licensing mainly between multinationals and domestic companies. In our case, stronger patents differentially affected multinationals and domestic firms. The rate of increase in multinational patenting was higher than that of domestic firms in part because stronger patents enabled domestic firms rely on external technology more rather than investing in internally generated technology. Thus, while we explain some of the puzzles posed by earlier work that conclude that stronger patents actually could decrease domestic innovation, we also highlight the conditions under which, stronger patents could facilitate MFT in which multinationals participate as licensors and domestic firms as licensees.

While considering a context of an integrated economy in which a single country exists in a multi-country world a few more considerations need to be taken into account. First, it matters where the benefits accrue and who incurs the costs. For instance, prior work has shown that stronger patents can result in the transfer of rents to multinationals located in developed countries (McCalman, 2001). Although this strongly points towards to the fact that the country undertaking the patent reform is likely to suffer the static losses, while most of the dynamic gains accrue to multinationals located abroad, other work has shown that in many developing countries, multinational innovations contribute substantially to technology change and economic growth. Eaton and Kortum (1996) and Keller (2001) for instance empirically show that multinational innovation contribute substantially to the technological change that occurs in many OECD countries; because most entities in developing countries spend relatively less on R&D relating to basic science they tend to rely more on innovations from foreign countries for their productivity. They show that OECD countries other than U.S., Japan, U.K., Germany, and France obtain over 90% of their productivity growth from ideas originating abroad. Thus to the extent that stronger patent protection hastens diffusion of technology stronger patents should result in dynamic gains. In this paper, we also explore how stronger patents influenced competition in Indian markets. Thus greater domestic competition accompanied by higher royalty payments, especially in markets in which technology can easily be sold in disembodied form, after patent reform would reflect the fact that stronger patents influenced domestic firms that would have otherwise been unable to enter by in-licensing technology. In our empirical analysis, we additionally focus on how patent reform influenced industry level royalty payments and competition. In addition we also explore, if these effects were larger in markets in which technology can be easily sold in disembodied form.

Finally, our paper also relates to the recent literature in strategy that examines how the development of institutions influences firm strategies. The strategy literature has largely focused on how differences between firm's influences firm strategy and relatively little work focuses on how institutions affect firm strategies. While it is true that resources and capabilities of a firm determine its strategies, recent work suggests that firm strategies are also responses to institutional changes or changes in the context that they function in.(Hoskisson et al. 2000; Meyer and Peng, 2005). Institutions play an interactive role by constraining or enabling a set of organizational actions (Ingram and Silverman, 2002). However while the role of institutions on firm strategy is acknowledged, the implications of institutional changes on firm strategy are insufficiently appreciated. We hypothesize that stronger IPRs should reduce transaction costs (North, 1990) and should facilitate arm's length licensing. We show how strengthening of Intellectual Property Regimes (IPR) influence a domestic firms' decisions to in-license technology versus developing it by themselves. In the case of multinationals we examine how stronger patents influence whether to participate in product markets or in MFT. Thus an additional contribution of this work is to show that institutions by reducing transaction costs and facilitating exchange, alters the value of a firm's capability and thus influences firm strategy. Firms with superior technical capability that do not have complimentary capability can exploit the existence of such markets and develop and license technology to others with superior complementary capability. Firms with inferior technical capability can now enter product markets by through in-licensing.

Model

We motivate the empirical analysis with a stylized model to derive predictions on strong patents facilitate licensing activity between domestic companies and multinationals. We assume that each firm requires two types of inputs or capabilities to enter the product market. These inputs are technology and manufacturing, which can broadly be thought of as including other types of complimentary capabilities such as marketing and distribution. We assume away differences between product markets in order to develop a tractable model. We assume that there are two types of firms, domestic and multinational firms. Multinational firm are assumed to be endowed with technology and they have to decide whether to participate in the product market or the MFT. Domestic firms however, are heterogeneous in their ability to generate technology. We model this heterogeneity by assuming that only a proportion of them can generate proprietary technology by investing in product R&D.

We assume that all firms differ in their ability to manufacture the end product, which is the differential ability to manufacture the product to suit local markets. We assume that domestic firms in general have higher manufacturing capability to manufacture product that suit local tastes and preferences. We assume that firms are homogenous in other dimensions, once again in the interest of analytical tractability. We develop a model in which both the product market and the market for technology are in equilibrium in which all firms enter at the same time.

<u>Notation and assumptions</u>

There are γ potential multinational and domestic entrants. As stated above, firms differ in their ability in how efficiently they can produce a product. In general although, efficiency is multifaceted we just assume that more efficient firms produce and sell a higher quantity denoted by q. Thus q is a summary measure of the differences in the ability to manufacture the end product. We assume that $0 \leq q \leq Q$

is a random variable which is distributed F(q) which reflects the ability of a domestic firm to produce the product. As stated above multinational firms also heterogeneous in their ability to manufacture the end product and on an average has lower manufacturing ability relative to domestic firms. We model this by assuming that q for a multinational firm is distributed G(q) where G(.) is identically distributed to F but lies to the left of F(q).[2]

The cost function for firms in the product market is cq where c is the marginal cost.[3] Ignoring product heterogeneity, we assume that the demand for the product D(p), is decreasing in p, the product price. Domestic firms are of two types: a proportion β are assumed to be capable of being capable of generating their own proprietary technology while the remaining firms are incapable of generating proprietary technology.

We adopt a reduced form approach to model MFT. Each licensor that participates in MFT earns license revenues of L. For analytical simplicity, we assume that $\tau + E \leq L$. Licensees buy technology at a price of τ. We do not model how τ is determined but instead, τ is simply assumed to be a decreasing function of the total number of licensors, M. Stated otherwise τ(M) with τ'(M)<0.

All licensors incur a cost of E, which reflect the costs of writing and enforcing contracts. We assume that stronger IPRs make it cheaper to enforce licensing contracts. Moreover, we also assume that it is cheaper to write and enforce contracts in markets in which technology is more amenable to be sold in disembodied form (disembodied industries, henceforth) costs. In order to reflect these assumptions E(1-θ)(1-α) reflects the cost of writing and enforcing contracts to a licensor where $0 \leq \theta \leq 1$ and $0 \leq \alpha \leq 1$ denote the strength of patents and the extent to which technology can be sold in disembodied form in a market. There are γ potential multinationals and domestic firms that can enter the market. Finally we assume that all licensors patent their innovations while only a λ proportion of producers patent their innovation. This is in line with past literature that producers typically have a variety of mechanism to protect their innovations and patenting may not be the dominant method of preventing misappropriation of intellectual property. Thus if M represents the total number of licensors in an economy and N the number of producers the total number of patents in an economy, ρ=M+λN.

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[2] In certain parts of the model we explicitly assume that G(q)=x+F(q) where $x \leq 0$.

[3] The fact that firms have the same cost structure but different levels of output can be rationalized as follows. Suppose the technology of a firm takes the form $q = \frac{L^2}{2}$ where L denotes the units of labor with δ being the process R&D ability bounded between δ^L and δ^H. The profit is given by $\frac{pL^2}{2} - cL$ where c is the unit cost of labor. The optimum output of a firm q*, for a given level of process R&D ability δ is determined by its first order condition pLδ – c = 0. Thus q* = $\left(\frac{c}{p\delta}\right)^2$ and the marginal costs are cq*.If δ is distributed K(. ; ρ) where ρ is a shift parameter in the sense of first order stochastic dominance with $f_\rho<0$, then the pr(q≤q*) is just $1 - K\left(\frac{c}{pf'(L)}; \rho\right)$ which is monotonically increasing in process R&D ability ρ. Thus, even when firms have the same factor costs, firms might produce different levels of output due to differences in marginal productivity.$q = \frac{L^2}{2}$ $q = \frac{L^2}{2} \frac{pL^2}{2} - cL$ $\frac{pL^2}{2} - cL$ $\left(\frac{c}{p\delta}\right)^2$ $\left(\frac{c}{p\delta}\right)^2$ $1 - K\left(\frac{c}{pf'(L)}; \rho\right)$ $1 - K\left(\frac{c}{pf'(L)}; \rho\right)$

Profits

With these assumptions profits of a multinational firm that participates in the product market earns a profit of $\pi_{MP} = (p - c)q$ while a multinational firm that participates in the technology market earns$\pi_{ML} = L - E(1 - \theta)(1 - \alpha)$.

Domestic firms those that choose to enter the product market by in-licensing earn a profit of $\pi_{DI} = (p - c)q - \tau(M)$. Those that decide to enter the product market by inventing their own proprietary technology earn $\pi_{DP} = (p - c)q$. Finally domestic firms that choose to license, earn $\pi_{DL} = L - E(1 - \theta)(1 - \alpha)$

Domestic firm's entry decisions

Domestic firms can enter the product market in two ways by generating proprietary technology or by in-licensing it from a licensor. Domestic firms that generate proprietary technology will enter product markets when they have "high" manufacturing capability. This is when (p – c)q – k > L – E – k or when $q > \frac{L-E}{p-c}$ Thus the probability that a domestic firm will enter the product market by generating proprietary technology is just $\beta\left(1 - F\left(\frac{L-E}{p-c}\right)\right)$ Similarly the probability that a domestic firms that has the ability to generate proprietary technology will out-license rather than use it to enter the product market is just $\beta F\left(\frac{L-E}{p-c}\right)$.

Domestic firms that do not have the capability to generate proprietary technology will enter by in-licensing if they can make positive profits by entering the product market by in-licensing technology from a licensor. Formally this condition is just (p-c)q – τ(M) >0 or when $q > \frac{\tau(M)}{p-c}$.$q > \frac{\tau(M)}{p-c}$ Thus the probability that a domestic firm without the capability to generate proprietary technology entering the product market is just $(1 - \beta)\left(1 - F\left(\frac{\tau(M)}{p-c}\right)\right)$.

Multinational firm's entry decisions

Since multinationals firms are endowed with technology, such firms will enter the product market if they have "high" level of manufacturing capability and participate in the MFT otherwise. Stated otherwise, they will enter product markets when $q > \frac{L-E}{p-c} q > \frac{L-E}{p-c}$ or participate in the technology market otherwise. This probability is just $1 - G\left(\frac{L-E}{p-c}\right) 1 - G\left(\frac{L-E}{p-c}\right)$.

Market Equilibrium

Market equilibrium involves two interrelated markets: The product market and the technology market. Equilibrium in product market implies that the quantity supplied by producers must equal the quantity demanded. The quantity supplied in the product market is the total quantity supplied by the participants in the product market. This condition is given by

$$D(p) = Q\left\{\beta\left(1 - F\left(\frac{L-E}{p-c}\right)\right) + (1-\beta)\left(1 - F\left(\frac{\tau(M)}{p-c}\right)\right) + 1 - G\left(\frac{L-E}{p-c}\right)\right\} \tag{1}$$

In the technology market, market clearing is more subtle. Any given licensor can sell as many licenses as required. The equilibrium condition is that the total license revenues (of all technology suppliers), should equal the total licensing payments. The former is L multiplied by the number of licensors and the latter the number of licensees multiplied by the license price τ(M). This condition is given by

$$L\gamma\left\{\beta F\left(\frac{L-E}{p-c}\right) + G\left(\frac{L-E}{p-c}\right)\right\} = \tau(M)\gamma(1-\beta)\left(1 - F\left(\frac{\tau(M)}{p-c}\right)\right) \tag{2}$$

To get some intuition into these market clearing conditions, figure 1 shows how M and p are related for each market clearing condition. The PP curve represents equilibrium in the product market, and TT curve represents equilibrium in the technology market. Both PP curve and TT curve are downward sloping, while the slope of the PP curve is steeper than that of the TT curve (all proofs are contained in the appendix). The intersection represents market equilibrium, with p^* and M^* as the equilibrium price and technology suppliers.

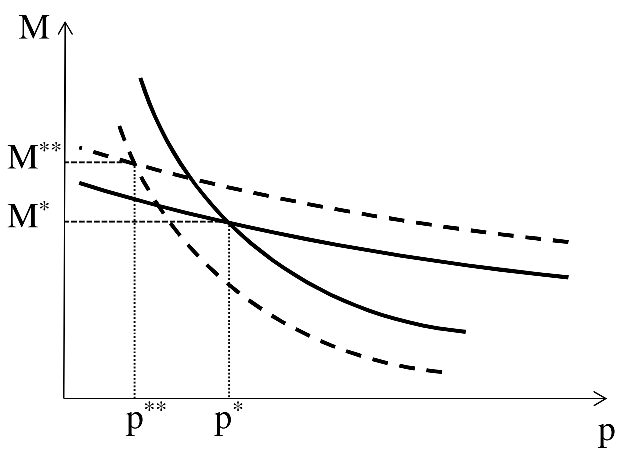

Figure 1 Equilibrium

The model has a number of testable predictions. The formal statements and proofs are all contained in the appendix. Here we state the results verbally. As shown in figure 1, the model predicts that stronger patents reduce the cost of entering into arm's length transactions to license technology. This should result in an increase in the number of firms that out-license technology, M. This result is in line with prior literature that suggests that stronger patents are pivotal to an innovator's decision to out-license technology rather than to exclusively use it to enter the product market (Green and Scotchmer, 1995; Merges, 1998; Arora and Merges, 2000). We state this result formally as a hypothesis below:

Result 1: $\frac{d\rho}{d\theta} > 0$. *A decrease in θ increases the number of patents filed in that country. Stronger patent protection increases the number of technology licensors.*

Increased number of licensors should have two effects on firms that are considering entering product markets. For domestic firms that have the ability to produce proprietary technology, stronger patents should dissuade entry into the product market. This is because stronger patents have the effect of reducing prices in the product markets. But on the other hand the availability of many licensors should also reduce cost of in-licensing technology to the domestic firms that do not have the ability to produce proprietary technology. This in turn should stimulate greater entry by such firms into the product market. Our model suggests that the net effect should be increased competition and a reduction in prices from stronger patents.

Result 2: $\frac{dp}{d\theta} < 0$. *A decrease in θ increases decreases prices in the product market. Stronger patents increase price competition.*

Note, that in our setup, multinationals have lower manufacturing ability. Given this, the reduction in incentives to enter product markets from stronger patents, is higher for multinational firms than for domestic firms that are capable of producing proprietary technology. This results in a disproportionate number of multinationals participating in MFT when patent protection is strengthened. Stated otherwise, if Φ_D is the number of domestic patents holders and Φ_M the number of multinational patent holders, $\frac{\partial \Phi_M}{\partial \theta} > \frac{\partial \Phi_D}{\partial \theta}$ Note that this result merely an artifact of there being more potential multinational entrants relative to domestic entrants, but rather because of the fact that multinationals have a greater probability of entering technology markets relative to domestic firms.[4]

Result 3: $\frac{\partial \Phi_M}{\partial \theta} > \frac{\partial \Phi_D}{\partial \theta}$. *Stronger patents increase the number of multinational patents by more than domestic patents.*

[4] Higher number of potential multinational relative to potential domestic entrants should increase both patenting as well as, product market entry by multinationals. But with an eye on the empirics, given that our empirics are based on India data, it is unlikely that the number of potential multinational entrants is higher than domestic entrants in most industries. For example if the number of trademarks was a for the amount relative product market entry rates by multinationals versus domestic firms, before patent reform the proportion of trademarks filed with the Indian Patent Office over total trademarks by domestic firms was about 85% and that of foreign firms was about 15%. After 2004 the proportions were 89% and 11%. Thus while the product market entry rates increased for domestic firms, it decreased for multinational firms (calculations based on annual reports of Controller General of Patents, Designs and Trademarks available at www.ipindia.nic.in last accessed, Dec10, 2011)

The model also suggests that the license payments in a market such increase with θ. This is because stronger patents increase the number of potential licensors in a market, which in turn stimulates even domestic firms with reasonable manufacturing capability to enter the product market despite not having the ability to generate proprietary technology. This result is also in line with other work in the literature that suggests that, licensing is prevalent in industries that have strong IPRs, especially when the ownership of downstream assets needed to commercialize products is concentrated in the hands of very few firms (Teece, 1986; Gans, Hsu and Stern, 2002). We formally state this as a hypothesis below.

Result 4: An increase in θ increases industry license payments. In-licensing is more prevalent when patents are stronger.

<u>Embodied vs. disembodied industries</u>

Embodied technology in general is sticky to the inventing firm and is hard to out-license, which the converse is true with disembodied technology. Disembodied technology can be de-coupled from the inventor relatively easily, and can be licensed out relatively easily. Thus disembodied technologies are likely to have relatively lower transaction costs (Williamson, 1985) and are more amenable to licensing. Stated otherwise disembodied technology is likely to have considerable transaction costs, ex ante for search and negotiation as well as, ex post to enforce contracts (Cassiman and Veugelers, 2006). Recall that in out setup it costs more for firms to license out disembodied technology given that the licensing costs are increasing the extent to which a technology is disembodiable reflected by α. All else equal, given that the transaction costs associated with licensing disembodied technology are likely to be lower, there should be more licensors and hence patents in markets in which technology is relatively disembodiable.

Result 5: $\frac{d\rho}{d\alpha} > 0.$ *The number of patents is higher in markets in which technology can be sold relatively easily in disembodied form.*

Most of the literature assumes that technology that is acquired from outside is typically of the disembodied kind. However, recent work such as that of Cassiman and Veugelers, (2006) point out that even embodied technology is often acquired externally by firms although a preponderance of studies have also shown that it is not as prevalent as in disembodied industries.

Given that multinationals are more likely to license out technology relative to domestic firms that are also technology holders, it follows that the difference between the number of patents held by multinational relative to domestic firms should be higher in markets in which technology is easily disembodiable. Stated otherwise, $\frac{\partial \Phi_M}{\partial \alpha} > \frac{\partial \Phi_D}{\partial \alpha}$

Result 6: $\frac{\partial \Phi_M}{\partial \alpha} > \frac{\partial \Phi_D}{\partial \alpha}$ *The difference between the number of patents held by multinational firms and domestic firms is higher in disembodied industries than in embodied markets.*

Given that prices are lower in markets in which there is a greater amount of licensing activity, the model suggests that the price competition should be higher in disembodied industries relative to embodied markets, or, $\frac{dp}{d\alpha} < 0$

Result 7: $\frac{dp}{d\alpha} < 0.$ *Price competition is higher in disembodied industries.*

Since greater number of licensors stimulates entry of even domestic firms that do not have the ability to generate proprietary technology, disembodied industries should also see greater licensing activity. Once again, this result is also in line with other work in the literature that suggests that licensing is prevalent in industries in which technology can be sold in a disembodied form (Arora, Fosfuri, Gambardella, 2002). We formally state this as a hypothesis below.

Result 8: An increase in α increases industry license payments. In-licensing is more prevalent when in disembodied industries.

<u>Effect of stronger patents in embodied versus disembodied industries</u>

Given that the transaction costs associated with licensing technology are even lower when patents are stronger and when the nature of technology is easily disembodiable, when patents are strengthened, due to a disproportionate increase in M, the number of licensors, the increase in patenting is higher with the strengthening of patents in disembodied industries relative to embodied markets. Stated otherwise, $\frac{\partial^2 \rho}{\partial \theta \partial \alpha} > 0$.

Result 9: $\frac{d^2 \rho}{d\theta d\alpha} > 0.$ *The increase in patents with a decrease in θ is in disembodied industries relative to in embodied markets.*

The fact that transaction costs associated with licensing technology are even lower when patents are stronger and when the nature of technology is easily disembodiable means that there is just greater entry into the product market by firms that are not capable of producing proprietary technology. These firms enter by in-licensing technology. This in turn implies that the price competition is more intense in such markets.

Result 10: $\frac{d^2p}{d\theta d\alpha} < 0$. *The decrease in price with a decrease in* θ *is more in disembodied industries relative to in embodied markets.*

Result 11: The increase in license payments with θ *is more in disembodied industries relative to in embodied markets.*

Data and variables

We test our hypotheses using data on patents granted by the Indian Patent Office filed between 1985 and until 2010. We use the recently enacted patent reforms in India to test our results.

Before dwelling on our measures, we provide a brief summary of the main changes to the Indian patent law in order to conform to the TRIPs mandate. Until 1972, the Indian Patent law was a continuation of the British Patents and Design Act of 1911. In 1972 to facilitate acquisition of indigenous industrial capability, the federal government enacted a new patent law that significantly weakened patent protection. This law effectively outlawed product patents and shortened the life of process patents to between 5-7 years and banning the product patents.

In 1994, the Indian government signed the Agreement on Trade Related aspects of Intellectual Property Rights (TRIPs treaty) and committed to making its patent law consistent with the global patent laws. A decade later, India through the enactment of the patent act of 2004, enacted a patent law consistent with the TRIPS mandate. The 2004 law once again allowed patenting products as well as processes for a term of 20 years from the date of filing. Another important change was the setting up of a specialized judiciary like that of the CAFC in the US to hear IP cases, by setting up of the Intellectual Property Appellate Board (IPAB).[5] We explore how the enactment of the new patent law influences domestic and multinational innovation and licensing.

To this end, we acquired data from two sources. First, from the Indian Patent Office, we acquired all the patents that were filed between 1984 and 2009, which amounted to 63020 patents. From this set of Indian patents we randomly sampled every 10th patent. Thus our dataset comprises of 6302 Indian patents filed between 1984 and 2009. Using the International Patents classes (IPC) class on a patent, we then mapped each patent to a US-SIC class using patent concordance classes at the US.PTO. We did this mapping as follows: We first took each IPC class on an Indian patent and then mapped them to US patent

[5] These courts came into being in middle of 2004.

classes using the concordance data available at the US.PTO web site.[6] Then we mapped each US patent class to one or more SIC codes once again using the concordance table available at the US.PTO.[7] Finally we manually mapped each US-SIC code with Indian NIC codes (industry code henceforth; a concordance table listed in the appendix).

In addition, in order to test our hypotheses that relate to industry-level license payments and competition, we additionally use the disaggregated data, from the Annual Survey of Indian industries (ASI), a dataset much like the economic census in the US, covers every establishment that has more than 3 registered employees from 1999 through 2008.[8] This dataset covers all institutions both domestic as well as multinationals. However in regressions in which we explore how industry level license payments varies with stronger patents we exclude privately we restrict our dataset to include only domestic firms – we removed all private limited companies from the sample since most foreign subsidiaries in India are privately held companies. Regressions that explore how industry level competition varies with stronger patents include all firms. Although we use disaggregated data on Indian firms, we aggregate this data at an industry level, for the following reason: neither do we know the identity of a firm in this sample nor do firms directly report the amount of royalty payments that they incurred in a year. However, the amount of royalty payments incurred by a firm is reported as non-operating expenditure which includes royalty payments, R&D investments, printing and stationery and staff welfare expenses. As we will describe in detail later, our method to construct the dependent variable that proxies for royalty payments relies on being able to separate out royalty payments from other items that constitute non-operating expenditure. The need to separate out royalty payments from other items that constitute non-operating expenditure, in addition to not being able to observe the identity of individual firms resulted in having to aggregate this data at the level of an industry annually. We also supplemented this data with yearly statistics on India population, federal government on education, number of trademarks filed with the Indian Trademarks office by Indian residents, from the World Bank data.

Our unit of observation is industry, year and region (North, South, East and West, described later) except for regressions that test how the number of patents filed by multinationals changed with stronger patents relative to that of domestic firms (results 3 and 6). Thus while we make use of 1472 observations

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[6] Listed at http://www.uspto.gov/web/patents/classification/international/ipc/ipc8/ipc_concordance/ipcsel.htm#a last accessed, November 5th, 2011.

[7] Listed at ftp://ftp.uspto.gov/pub/taf/sic_conc/, last accessed Dec 2nd 2011. A patent that matched with multiple SIC classes were counted as belonging to all those SIC classes.

[8] We only used data on public limited, partnership and sole proprietorship firms and excluded private limited firms, government companies and trusts. We excluded private limited firms because (a) many of them are subsidiaries of multinationals and (b) we cannot decipher the identity of individual firms in the data.

which is a balanced panel comprising of observations that relate to 16 manufacturing industries,[9] covering 4 regions, covering 23 years.

Dependent variables

Patenting activity (ρ): We measure the amount of patenting activity using the number of patents filed in an industry per million Indian residents**.** This variable reflects the number of Indian patents filed with the Indian Patent Office (IPO) in a year by industry per million Indian residents. By industry code we aggregated the number of patents filed with the IPO in a year by industry. We then divided the resulting number by the number of Indian residents in million.

Price competition (p): We measure price competition using the Hirschman Herifindahl Index (HHI) of an industry in a year. Using the ASI data and using all firms, we calculated the HHI as the square of a firm's share of revenues of the total industry revenues in a year multiplied by 100. A higher HHI reflects higher concentration and hence higher prices. We use this measure to test if competition increased with stronger patents. In our regressions, we use the log of this measure as our dependent variable.

Non-operating expenses: In our sample firms report non-operating expenditure which includes royalty payments, R&D investments, printing and stationery and staff welfare expenses. We use the natural log of this measure after deflating it by the whole sale price Index or WPI in the regressions. We rely on this measure to construct our measure of royalty payments (Ω).

We calculated industry license revenues in a year as follows. We first regressed non-operating expenses in log against proxies for R&D investments, printing and stationery, staff welfare expenses and managerial remuneration. To this end we regressed non-operating expenses in log against, industry patents held with the IPO in a year in a region (lagged by a year in logs), sales revenues, total number of employees, total supervisor staff (all in logs) along with industry, region and year dummies. We then calculated our proxy for license payments that varies by year, industry and region by using the coefficients on year, industry and region dummies.

Specifically we first estimated the following regression.

$$\log(\text{non} - operating\ \exp_{rjt}) = \beta_0 + \beta_1 logpatents_{rjt} + \beta_2 logworkers_{rjt} + \beta_3 logsupervisorystaff + \beta_4 logrevenues + \beta_r R + \beta_j J + \beta_t T + \epsilon_{rjt}$$

where R, J and T denote region, industry and year dummies and subscripts r, j and t denote industry, region and year. We then calculated our proxy as $\log(license\ payments_{rjt} = \log(non -$

[9] They are automobiles, chemicals, computer, construction, electrical instruments, electronics, food, medical instruments, metals and mining, petroleum, rubber and plastics, telecommunication, textiles, lumber and wood, pharmaceuticals and biotechnology and a residual category that includes patents that could not be matched to an industry code.

$operating \exp_{rjt}) - \widehat{\beta_1} logpatents_{rjt} - \widehat{\beta_2} logworkers_{rjt} - \widehat{\beta_3} logsuperstaff_{rjt} -$
$\widehat{\beta_4} logsuperstaff_{rjt}$, where the $\widehat{\beta_s'}$ denote the estimated coefficients.

Proportion of multinational patents: In order to test how multinational patenting changes relative to domestic patenting we compare how the proportion of multinational patents changed relative to the proportion of Indian patents. To this end, we categorize the assignee on a patent as (a) multinationals if the assignee listed on a patent reported an address outside India and was not also the inventor and the patent, (b) domestic company if the assignee listed on a patent reported an address in India and the assignee listed on the patents was not the inventor (c) others foreign, if the assignee listed on a patent reported an address outside India and was also the inventor on the patent or a foreign university with address outside India (d) others local, if the assignee listed on a patent reported an address in India and was also the inventor on the patent (e) or an Indian university with address in India. In our regressions we combine categories (c) through (e) (others, henceforth) into a single category called others based on the fact that this group are likely to have low levels of manufacturing capability and perhaps similar or lesser R&D capability on an average relative to multinationals.

Table 1 provides a break up by year filed of granted patents that relate to the different industry segments. It also distinguishes between whether the assignee was a multinational, domestic company, Indian individual or others. Table 1 shows that on an average multinationals file about 10 times more patents in India relative to domestic firms (78% to 8%). The financial crises in the mid 1980's had negatively influence innovation as evidenced by only a handful of patents there were filed during that period. Moreover, while to proportion of multinational patents increased by about 5% with reform, it increased by only 1% for domestic firms.

Independent variables and controls:

Proxy for strength of patents: We use two variables that proxy for the strength of patents. One, is a time-varying proxy *Period I dummy*=1 if the focal patent was filed on or before 2005. Note that since this variable varies exclusively with time, we will not be able to separately identify the effect of stronger patents from unobserved time variations. We hence rely on whether the differences were higher in embodied markets relative to disembodied industries.

In addition, as a robustness check, , we also constructed an alternative measure that is based on the proportion of Intellectual Property (IP) litigations were decided in favor of the IP holder (*proportion for* henceforth). We calculated this variable by separately aggregating the total number cases that were decided in favor of the IP holder and the total number IP infringement law suits by industry and year.For every year, we calculated these two measures separately for each industry in our sample. We then by calculated this variable by dividing the cases that were decided in favor of the IP owner by the total number of cases. Since this proxy varies both by industry and time we use this measure to show that unobserved time variations do not affect our principal results of interest.

Proxy for disembodied nature of an industry: We measure the extent to which an industry is disembodied using the proportion of US patents held by universities over the total industry patents in an industry in a year. In our regressions, however, we use estimate coefficients separately for US university patents (and US total patents separately just US university patents and US total patents, henceforth). We constructed these measures separately calculating the total university patents and total industry patents respectively.

University-based innovations tend to be based on science, which also makes the invention easier to articulate and codify, and also to patent. As a result, technologies from universities are also well suited for licensing (Arora and Gambardella, 1994; Gambardella and Giarratana, 2007). Thus the extent to which universities patent in an industry could reflect the extent to which innovations are licensable.

Time dummies: We also control for time effects using 22 time dummies, one each for every year of application in our sample. Recall that the year of filing of patents ranges is between 1985 through 2008.

Proxies for technology advances in an industry We also control for the number of technological breakthroughs in an industry using the total number of US patents (filed with the US Patent and trademark office) held by non-Indian assignees (assignees with an address outside India, excluding foreign subsidiaries of Indian companies) in a year.

Industry dummies: We also control for industry effects using 15 industry dummies, one each for every NIC code. The residual category constitutes patents for which we were unable to map NIC codes. These constituted 24 patents in all.

Region dummies: We also control for region effects using 3 region dummies, one each for every North, South and Western regions, based on the regional office that the patent was filed in. India has four regional patent offices and the region dummy variable was coded based on the regional office that the patent was filed in India. The residual category denotes the eastern region.

Proxy for the size of offshore market opportunity: We also control for the size of the Indian market opportunity using the total number of trademarks, lagged by a year filed with the Indian trademark office, lagged by one year, gathered from the World Bank data. The number of trademarks reflects the number of products and services introduced in an economy in year and thus reflect the market opportunity in a country. Since this measure could potential be endogenous we use the non-resident filed in China once gain collected from the World Bank data as an instrument.

Proxy for prices: In certain specifications we use the wages per man-day as a proxy for prices which are unobserved. We calculated this variable by dividing the industry salaries and wages in the ASI data by the total number of man days for that industry.

Descriptive statistics for all the variables are included in Table 2.

Empirical analysis

We start with providing evidence for our hypotheses using simple comparison of means. In table 3A, we first compare how the Indian patent reform increased patenting. From column 3 of table 3A, consistent with result 1, we find that the number of patents per million Indian residents filed with the IPO was higher after reform than before it. As also hypothesized, the price competition was higher after reforms than before it, while the industry level license revenues were higher after reform than before it.

In order to test if the effects were different in disembodied industries versus embodied industries, we split our sample into two, based on whether the level of disembodiment was higher or lower than the average level of disembodiment in the sample. Tables 3B shows that the increase in patenting activity was higher in disembodied industries than in embodied industries by about 0.03 patents per million. Similarly as also hypothesized table 3C shows that the decrease in price competition was higher in disembodied industries than in embodied industries by about 10%. Finally table 3D shows that the increase in license payments by domestic firms was also higher in disembodied industries relative to embodied industries. While the non-parametric analysis above supports our hypotheses, it does not control for a variety of other factors. We turn towards regressions.

Patenting activity

We start by exploring how the number of patents changed after the patent reform. We had 3 sets of results with respect of patenting activity. We had hypothesized that patenting activity should increase with stronger patents and also that they should increase by more in disembodied industries relative to embodied industries. Finally we had also hypothesized that the increase in patenting activity should be more in disembodied industries relative to embodied industries.

In order to test these hypotheses, using patents per million Indian residents as a dependent variable we implement a set of OLS regression to explore the effect of reform on patenting activity. We start with using period I dummy to test the effect of reform is specification 1. We additionally control for industry and region effects using 15 industry and 3 region dummies. We also control for any time varying technology breakthrough in an industry using the number of lagged US.PTO patents that were filed in a industry in a year in natural log. Given that our main independent variable does not vary by time, we additionally add a control for the amount of scientific talent available in India using 5 year average federal education spending in logs. Results of specification 1 suggest that in the period before 2005 the number of patents in a region was lower by about 20 patents per million or by about 25% on an average. All other coefficients are in the expected direction with both industry level R&D as well as education spend being positively associated with patenting activity. Also on an average, industry that experienced higher technological breakthrough (proxied by lag log total US patents) in a year also experienced higher patenting activity in India.

In table 5 we test if patenting activity is higher in disembodied in specifications 1 and 3 using our proxies for the strength of patents. To this end we include the number of US patents held by universities in an industry in a year as an additional regressor. Both specifications 1 and 3 suggest that patenting activity is higher in disembodied industries. For example, specification 1, suggests that on an average, patenting activity is higher in disembodied industries. From specification 1, doubling only university patents is likely to increase total patents per million by about 21.3% whereas merely doubling industry patents by holding university patents constant increases total patents per million by only 8%.. Thus an industry with twice the level of disembodiment is likely to have about 13.2% higher patenting activity.

Specifications 2 and 4 of table 5 suggest that the increase in patenting activity with stronger patents was higher in disembodied industries. For instance, using specification 2, with reforms, increasing total US patents while keeping the US university patents constant, is likely to increase patenting activity a by only 13%. Whereas with reforms, doubling US university patents, the patenting activity is likely to increase by about 22%. Thus stronger patents are likely to increase patenting activity by about 9% more in disembodied industries. We get qualitatively similar results even if we interact our other proxy for the strength of patents with US University and total patents.

Thus results in tables 4 and 5 suggest that stronger patents increase patenting activity and increase patenting activity by more in disembodied industries. Also disembodied industries in general have a greater amount of patenting activity on account of possibility for licensing. Overall, the differential increase in patenting between disembodied and embodied industries suggest that stronger patents also facilities MFT. This result is in line with prior work that suggest that stronger patents facilitate licensing (Gans, Hsu, Stern, 2002; Arora, Fosfuri, Gambardella, 2001).

Competition

Next we explore how the price competition changed after the patent reform. Our hypotheses suggested that competition should decrease with stronger patents and by more in disembodied industries relative to embodied markets. Also we had also hypothesized that disembodied industries should on an average be more competitive than embodied markets.

Using log HHI in log as a dependent variable we now test these hypotheses. Recall that we calculate log HHI using total revenues. To the extent that firms are price takers this measure should reflect the shares in terms of output. However, since the market price is endogenous to industry quantity marginal cost, α and θ act as exclusion restrictions to identify market quantity and derive an estimating equation that includes marginal costs. In our regression we hence include a proxy for marginal cost which is the labor cost per man day (please see appendix 2 for a more detailed discussion of how we derived the regression equation).

We add the same controls as before except industry R&D and education spends. We start by exploring how stronger patents affected competition. Our results suggest that patent reform increased competition. Results of specification 1 of table 6, suggests that prior to the patent reform, on an average industry concentration was higher by about 10%. In specification 2, we use our other proxy for the strength of patents and find that our qualitative results are unchanged. Specification 2 suggests that doubling the proportion of cases decided in favor of the owner of IP, decreases concentration by about 5%.

Specifications 1 and 2 of table 6 also suggest that the industry concentration is lower in disembodied industries. For instance specification 1 suggests that that the industry concentration is likely to lower by between 6-7% on an average (p-value spec. 1 – 0.09; spec. 2 – 0.07). This is an interesting result. Prior work suggests that whether supply of technology increases or decreases competition depends not just on the existence of MFT, but also on how fragmented the ownership of complementary assets is (Gans, Hsu, Stern, 2002). When the ownership of complementary assets is concentrated with very few firms, increase in technology supply need not decrease competition. Given that our earlier results suggested that technology supply is indeed higher in embodied markets, if complementary assets were in fact concentrated with a few firms, we should not see a difference in competition between disembodied and embodied markets. These results suggest that ownership of complementary assets may not be that fragmented so that an increase in technology supply also decreases competition.

In specifications 2 and 4 of table 6, we test if stronger patents decreased industry concentration by more in disembodied industries relative to embodied industries. To this end, as before we interact period 1 dummy with US university patents and US total industry patents. Specification 2 of table 6 shows that doubling US university patents is likely to decrease concentration by 16% lower concentration before reform and by 23% after it. Thus with embodied industries the average decrease in concentration with stronger patents is likely to be about 7%. Specification 2 also shows that doubling only total US patents and keeping the university patents constant is likely to have a lower concentration by about 16% after reform and just 14% before it. Thus with disembodied industries the average increase with stronger patents is likely to be only about 2%. In specification 4, we get similar results even if we use proportion for as an alternative measure of the strength of the patent regime. Thus the effect of reform on industry concentration is likely to be more pronounced in disembodied industries.

License revenues

Next we explore how the industry license revenues changed after the patent reform. Our hypotheses suggested that license revenues should increase with stronger patents and by more in disembodied industries relative to embodied markets. Also we had also hypothesized that the license payments should be higher in disembodied industries relative to embodied industries.

Using our proxy for license revenues we now test these hypotheses. We use the same independent variables as in table 7 with the exception of labor cost per man day. Specifications 1 of table 7, suggest that the license payment are likely to be higher by about 26% after reform. Moreover specification 1 also suggests that license payments are likely to be higher in disembodied industries. For instance, specification 1 suggests that when the number of university patents is doubled the license payments in an industry are likely to be about 19.4% higher whereas when only the non-university patents are doubled, the license payments are likely to be only about 6% higher. Thus in an industry that has twice the ratio of university patents the license payments are likely to be about 13.4% higher. These results are in support of our hypotheses. Specification 3 suggests that using an alternative proxy for the strength of patents leaves our results unchanged.

In specifications 2 and 4 of table 7, we test if stronger patents increased industry license payments by more in disembodied industries relative to embodied industries. To this end, as before we interact period 1 dummy with US university patents and US total industry patents. We use table 7A to interpret the results of specifications 2 and 4. The left panel of table 7A suggests that an industry with double US university patents is likely to have 11% higher license payments before reform and by 18% after it. Thus with disembodied industries the average increase in industry level license payments with stronger patents is likely to be about 7%. An industry that has twice the number of non-university US patents is likely to have a higher license payments by about 7% after reform and just 5% before it. Thus with embodied industries the average increase in license payments with stronger patents is likely to be about 2%. The diff-in-diff effect is thus 5% (std. err. 0.03; p-val.0.10) implying that industry level license revenues increase by more in disembodied industries relative to embodied industries with reform. In specification 4, we get similar results even if we use proportion for as an alternative measure of the strength of the patent regime. Thus stronger patents are likely to increase industry license payments by more in disembodied industries.

Multinational patenting vs. domestic patenting

Recall that a multinational becomes a licensor is $G\left(\frac{L-E}{p-c}\right)$ and that of a domestic firm is .$F\left(\frac{L-E}{p-c}\right)$ Our theory suggests that L, p and E are both determined by θ and α. In our regression the prices are essentially unobserved. However, we use time, region and industry dummies in our regressions instead of prices. Also in regressions in which we use proportion for as a proxy for the strength of patents we additionally use interactions of time dummies interacted with industry dummies. As before, we use wages per man hour as a proxy for marginal costs. In table 8, we estimate a multinomial logit regression in which we explore how the proportion of multinationals and domestic patenting changes with stronger patents. In our regressions in table 7, the left out category are others.

Table 7 shows that the reform increased the proportion of multinational patents by 90% lower relative to that of others but only by 19% lower for a domestic firm prior to the reform. Thus the patent reform increased the proportion of multinational patents by more (difference 71%; std. err – 0.45; p-val-0.08). Moreover, relative to that of domestic firms the proportion of multinationals patents is higher in disembodied industries relative to embodied industries. Using specification of table 1, doubling the number of US University and total patents increases the proportion of multinational patents by 12% whereas merely doubling the US university patents increases the proportion of multinational patents by 51%. Thus doubling disembodiment increases the proportion of multinational patent by 44% (std. err. – 0.10; p-value – 0.07). With domestic firms doubling disembodiment increases patents only by 21% (std. err. – 0.10). The doubling disembodiment increases the proportion of multinational patents by 23% (std. err – 0.14; p-value 0.10).

Thus to summarize our empirical results, strengthening the patent regime, on average, increases the patenting activity, decreases prices and in-licensing. Moreover, the increase in patenting and the decrease in price are higher in disembodied industries relative to embodied industries. Also license payments are higher in embodied industries relative to embodied industries. Finally, the probability that a multinationals patents increases by more than domestic industries.

Alternative explanations

Our main independent variable, period I dummy varies only by time. Thus it is plausible that this variable picks up unobserved variations over time. However our other proxy for stronger patents, proportion for, yields qualitatively similar results. Also if period I dummy was merely picking up other unobserved time variation, why should competition decrease by more in disembodied industries? Similarly why should both patenting activity and license payments increase by more in disembodied industries relative to embodied industries?

Also our proxy for the extent to which an industry is disembodied is based on patenting patterns in another country namely the US. However the extent to which an industry is disembodied may be different in India. This suggests that it is plausible that the measure for disembodiment is measured with error. Given that most of our regressions are linear specifications, it is likely that this mis-measurement introduces attenuation bias. But this should only bias our coefficients against finding the results we do. Stated otherwise, if in fact the extent to which an industry is disembodied is measured with error, the true magnitude of our results should be higher.

Finally in the regressions that explore how competition changes with stronger patents, price is unobserved. Moreover it is plausible that our assumption of price taking behavior might be incorrect. If this is true, price is essentially an omitted variable in these regressions. However, to the extent to which price is uncorrelated with the independent variables, our results are likely to be unaffected by the omission of price. Why should price be correlated with our proxies for stronger patents or the extent to be an industry is disembodied unless the patents reforms by themselves were driven by higher prices or the courts reacted more in favor of the patent owner because of prices prevailing in an industry? The latter is a possibility given the recent spate of cases that were decided against multinationals purely based on prices such as the cases of Novartis vs. Cipla (available at http://spicyipindia.blogspot.com/2011/06/novartis-v-cipla-cipla-wins-pre-grant.html last accessed Nov 9th 2011) or Cipla vs. Roche (available at http://www.indiankanoon.org/doc/401740/ last accessed Nov 10^{th} 2011) Although we acknowledge this as a limitation of our study, we also note that our results are qualitatively similar with period I dummy.

Discussion

In this paper, we explored how the recently concluded patent reforms in India, which strengthened patents, affected competition and innovative activity in India. In particular, we explored why multinational patenting increased by more than domestic patenting activity. In this paper we hypothesize that strengthening patents is likely to increase multinational patenting by more relative to that of domestic firms because of two reasons: First is because of differential ability to commercialize technology – when complementary assets required to commercialize technology is concentrated with domestic firms and it is relatively very expensive for multinationals to acquire complementary assets. Second is because of differential ability to do R&D – when domestic firms are relatively less capable of doing R&D relative to multinationals. Due to these differences, stronger patents just increase incentives for specialization resulting in multinationals specializing as technology suppliers and domestic firms specializing in commercializing technology.

Our empirical results showed that stronger patents in India increased multinational patenting by more relative to domestic patenting. Moreover stronger patents increased competition and in-licensing as evidenced by lower HHI and higher industry license payments after reform. All these effects were also more pronounced in disembodied industries in which technology can be separately with ease relative to embodied industries. Thus as the broader strategy literature suggests stronger patents can create opportunities for licensing and facilitates MFT (Arora, Fosfuri, Gambardella, 2002; Teece, 1986; Gans Hsu and stern, 2002). Thus in essence we build on the broader strategy literature and identify a set of conditions under which stronger patents can actually reduce competition as opposed to increasing industry concentration.

Our results thus have significant managerial implications. An obvious implication of our results is that for domestic firms with significant downstream capability, stronger patents is not likely to be a threat, but rather beneficial, because with stronger patents such firms are just likely to have better access to cutting edge technology. For multinationals, stronger patents are likely to provide cheaper growth opportunities – by facilitating out licensing, multinationals can just out-license their technology to domestic firms rather than embedding the technology into a product which would require large sunk investments. These results are in line with previous work that suggests that stronger patents promotes efficiencies in R&D and production (Lanjouw, 1998) – by specializing in upstream technology multinationals can perhaps benefit from larger scale R&D programs, which letting the more efficient downstream manufacturers to manufacture the end product.

Our results also have significant policy implications. In particular the paper identifies the conditions under which patents can actually increase competition rather than decreasing it. By facilitating MFT, stronger patents just facilitate more entry and increases price competition. This consequence of stronger patents has largely

As with most work, ours also has limitations. Our main limitation is imposed on us by the nature of the data. First, our results based on an analysis of a handful of patents. However our results appear robust to different measures of the strength of patents, which provides us confidence in these results. However whether our results are driven by the idiosyncratic country context that this study is based on at this point is unclear. Further our analysis is at the level of an industry although our story is at the level of a firm. Thus empirical analysis of how individual firms respond to stronger patents will be an avenue for future work as will exploring whether the effects that we find are merely driven by factors idiosyncratic to India. Nonetheless we believe the paper does contribute in a novel way to understanding the possible effects of strengthening patent protection in a country that hitherto had a weak IPR by especially highlighting the conditions under which stronger patents can increase competition rather than decreasing it.

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Tables

Table 1 Indian patents by assignee category filed from 1985-2008

Variable	Description	Source of variation	N	Mean	Std. Dev
Patent activity	Total number of patents per million Indian residents	Industry, year, region	1472	0.08	0.10
Price competition	Log of Hirschman-Herfindahl Index	Industry region year	1472	0.61	0.97
License revenues	Non-operating expenses adjusted for R&D, staff welfare expenses, printing and stationery and managerial compensation	Industry, region, year	1472	11.87	5.58
Period I dummy	=1 for years prior 2004, the year in which the patent reform was enacted	Year	1472	0.78	0.40
Alternate proxy for strength of IPR – Log proportion for cases	ln(# cases awarded in favor of the IP owner in a year and region) - ln(1+total no. of IP cases for that year and region)	Industry, year, region	1472	-0.79	0.40
Multinationals	Proportion of multinationals that filed for patents with IPO	Patent	6302$^{\pm}$	0.79	0.41
Domestic Firms	Proportion of Indian firms that filed for patents with IPO	Patent	6302	0.07	0.19
Others	Proportion of universities and individuals that filed for patents with IPO	Patent	6302	0.14	0.07
R&D Spend	Log Industry level R&D spend lagged by one year in rupees in million	Industry, region, year	1472	11.96	5.56
Education spend	5 year moving average education spending per million residents	Year	1472	12.89	1.27
Total patents held by non-Indian universities	Log of lagged number of granted patents in an year at the US.PTO held by non-indian universities	Industry, year	1472	4.51	1.93
Total US patents held by non-Indian assignees	Log of lagged number of granted US in an year at the US.PTO	Industry, year	1472	7.81	1.91
Proxy for size of the market opportunity	Log number of total trademarks filed in India	Year	1472	10.80	0.59
Instrument for market opportunity	Log number of total trademarks filed in China	Year	1472	12.37	0.79
Time dummies^{+}	22 time dummy one each for years 1985 through 2007	Year			
Region dummies	3 region dummies, one each for each North, South, and Western regional patent offices in India. The left out region is the Eastern region	Region			

Notes: $^{+}$ We use time dummies in regressions that use *proportion for* as a proxy for the strength of IPR. $^{\pm}$For regressions that test how multinational patenting changed vis-à-vis domestic patenting, the number of observations are 6302 because the unit of observation is a patent. For the rest of the regressions the unit of observation is industry, region and year and the number of observations are 1472.

Table 2 Indian patents by assignee category filed from 1985-2008

Year	Domestic firms	% of total	Multinationals	% of total	Total
1985	21	0.10	159	0.74	214
1986	16	0.09	117	0.69	169
1987	8	0.11	57	0.76	75
1988	3	0.20	12	0.80	15
1989	0	0.00	2	1.00	2
1990	0	0.00	9	1.00	9
1991	0	0.00	1	0.33	3
1992	1	0.20	4	0.80	5
1993	2	0.40	3	0.60	5
1994	0	0.00	4	1.00	4
1995	9	0.12	57	0.77	74
1996	13	0.07	153	0.83	185
1997	26	0.08	260	0.84	310
1998	32	0.09	279	0.79	355
1999	38	0.18	142	0.65	217
2000	34	0.10	235	0.71	331
2001	31	0.05	425	0.74	573
2002	33	0.05	516	0.79	651
2003	37	0.06	499	0.74	670
Before reform	**304**	**0.08**	**2934**	**0.76**	**3867**
2004	58	0.08	553	0.74	747
2005	75	0.07	884	0.88	1010
2006	39	0.07	445	0.85	523
2007	23	0.17	96	0.73	132
2008	20	0.87	3	0.13	23
After reform	**215**	**0.09**	**1981**	**0.81**	**2435**
Total	**519**	**0.08**	**4915**	**0.78**	**6302**

Table 3A Patents filed per million Indian residents

	After	Before	Difference
Patents per million	0.13	0.09	0.05***
	(0.00)	(0.00)	(0.00)
Log license revenues	11.99	11.73	0.26***
	(0.03)	(0.04)	(0.05)
Log HHI	0.56	0.64	-0.08***
	(0.02)	(0.02)	(0.03)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 3B Patents per million before and after reform by type of Industry

	Disembodied	Embodied	Diff
After	0.15	0.10	0.05
	(0.00)	(0.00)	(0.01)
Before	0.09	0.07	0.02
	(0.00)	(0.00)	(0.00)
Diff	0.06	0.03	0.03***
	(0.00)	(0.00)	(0.01)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 3C Log HHI before and after reform by type of Industry

	Disembodied	Embodied	Diff
After	0.47	0.59	-0.12
	(0.02)	(0.02)	(0.03)
Before	0.62	0.64	-0.02
	(0.02)	(0.02)	(0.03)
Diff	-0.15	-0.05	-0.10**
	(0.04)	(0.03)	(0.05)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 3D Log license revenues before and after reform by type of Industry

	Disembodied	Embodied	Diff
After	12.03	11.84	0.19
	(0.02)	(0.02)	(0.03)
Before	11.73	11.73	0.00
	(0.02)	(0.02)	(0.03)
Diff	0.30	0.11	0.19**
	(0.03)	(0.03)	(0.05)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 4 OLS of patenting activity

	Spec. 1	Spec. 2	Spec. 3	Spec. 4
Period I dummy	-0.02 ***			
	(0.00)			
Proportion of cases in favor of IP		0.09 ***	0.06 ***	0.05 ***
		(0.01)	(0.01)	(0.01)
Log industry R&D spend	0.03 *			
	(0.02)			
5yr- avg. educ. spending per million	0.04 ***			
	(0.25)			
log(lagged total US patents)	0.07 ***	0.06 ***	0.07 ***	0.08 **
	(0.02)	(0.02)	(0.02)	(0.03)
Constant	0.06 ***	0.03	-0.39 ***	3.44 **
	(0.00)	(0.02)	(0.03)	(1.73)
N	1472	1472	1472	1472
Adjusted R-squared	0.46	0.35	0.51	0.69
Industry dummies (15)	Y	Y	Y	Y
Time dummies (22)	N	N	Y	Y
Time dummies X industry dummies (330)	N	N	N	Y
Region dummies (3)	Y	Y	Y	Y

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 5 – OLS regressions of patents per billion by nature of Industry

	Spec. 1	Spec. 2	Spec. 3	Spec. 4
Period I dummy	-0.02 ***	-0.01 ***		
	(0.00)	(0.00)		
Log (lagged US univ. patents)	0.21 ***	0.30 ***	0.22 ***	0.23 ***
	(0.03)	(0.02)	(0.04)	(0.02)
Log(lagged US total patents)	0.08 ***	0.10 ***	0.07 ***	0.09 ***
	(0.02)	(0.02)	(0.01)	(0.02)
Period I* Log (lagged US univ. patents)		-0.22 ***		
		(0.04)		
Period I* Log (lagged US total patents)		-0.09 ***		
		(0.01)		
Log industry R&D spend	0.02 **	0.02 **		
	(0.01)	(0.01)		
Proportion of cases in favor of IP			0.09 ***	0.08 ***
			(0.01)	(0.01)
Proportion for * Log (lagged US univ. patents)				0.12 ***
				(0.03)
Proportion for * Log (lagged US total patents)				0.04 **
				(0.01)
5yr- avg. educ. spending per million	0.03 ***	0.02 **		
	(0.01)	(0.01)		
Constant	0.23 ***	0.25 ***	0.41 ***	0.49 ***
	(0.04)	(0.04)	(0.04)	(0.03)
N	1472	1472	1472	1472
Adjusted R-squared	0.48	0.51	0.41	0.70
Industry dummies (15)	Y	Y	Y	Y
Time dummies (22)	N	N	Y	Y
Region dummies (4)	Y	Y	Y	Y

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 5A Marginal effects

	Disembodied	Embodied	Diff		Disembodied	Embodied	Diff
Period I	0.08	0.01	0.07	**At average**	0.22	0.09	0.13
	(0.04)	(0.04)	(0.05)	**proportion for**	(0.02)	(0.03)	(0.03)
Period II	0.31	0.10	0.21	**At twice**	0.34	0.13	0.21
	(0.02)	(0.02)	(0.03)	**proportion for**	(0.03)	(0.02)	(0.04)
Diff.	0.23	0.09	0.14***	**Diff.**	0.12	0.04	0.08**
	(0.04)	(0.05)	(0.05)		(0.03)	(0.03)	(0.04)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 6 – OLS regressions of competition in an industry

	Spec. 1	Spec. 2	Spec. 3	Spec. 4
Period I dummy	0.10 ***	0.31 **		
	(0.00)	(0.14)		
Log (lagged US univ. patents)	-0.20 ***	-0.22 ***	-0.21 ***	-0.20 ***
	(0.02)	(0.02)	(0.02)	(0.01)
Log(lagged US total patents)	-0.15 ***	-0.16 ***	0.14 ***	-0.11 ***
	(0.03)	(0.03)	(0.02)	(0.01)
Period I* Log (lagged US univ. patents)		0.06 **		
		(0.03)		
Period I* Log (lagged US total patents)		0.02 ***		
		(0.00)		
Proportion of cases in favor of IP			-0.05 ***	0.18 ***
			(0.01)	(0.02)
Proportion for * Log (lagged US univ. patents)				-0.10 ***
				(0.01)
Proportion for * Log (lagged US total patents)				-0.05 ***
				(0.00)
Labor per man hour employed	0.03 ***	0.03 ***	0.02 *	0.02 *
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	1.51 ***	1.48 ***	1.23 ***	0.93 ***
	(0.45)	(0.45)	(0.44)	(0.03)
N	1472	1472	1472	1472
Adjusted R-squared	0.48	0.51	0.57	0.60
Industry dummies (15)	Y	Y	Y	Y
Time dummies (22)	N	N	Y	Y
Region dummies (4)	Y	Y	Y	Y

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 6A Marginal effects

	Disembodied	Embodied	Diff		Disembodied	Embodied	Diff
Period I	-0.16	-0.14	-0.02	**At average**	-0.20	-0.11	-0.09
	(0.03)	(0.03)	(0.03)	**proportion for**	(0.01)	(0.01)	(0.02)
Period II	-0.23	-0.16	-0.07	**At twice**	-0.31	-0.16	-0.15
	(0.02)	(0.03)	(0.03)	**proportion for**	(0.02)	(0.01)	(0.02)
Diff.	-0.07	-0.02	-0.05*	**Diff.**	-0.10	0.06	-0.06**
	(0.03)	(0.05)	(0.03)		(0.03)	(0.02)	(0.03)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 7 – OLS regressions of license revenues in an industry

	Spec. 1	Spec. 2	Spec. 3	Spec. 4
Period I dummy	-0.26 ***	-0.49 **		
	(0.04)	(0.14)		
Log (lagged US univ. patents)	0.19 ***	0.17 ***	0.19 ***	0.19 ***
	(0.03)	(0.02)	(0.03)	(0.03)
Log(lagged US total patents)	0.06 **	0.07 ***	0.06 ***	0.03 ***
	(0.01)	(0.01)	(0.01)	(0.01)
Period I* Log (lagged US univ. patents)		-0.06 ***		
		(0.02)		
Period I* Log (lagged US total patents)		-0.02 ***		
		(0.01)		
Proportion of cases in favor of IP			0.17 ***	0.12 ***
			(0.02)	(0.03)
Proportion for * Log (lagged US univ. patents)				0.10 ***
				(0.02)
Proportion for * Log (lagged US total patents)				0.06 **
				(0.03)
Constant	14.87 ***	14.51 ***	14.72 ***	14.41 ***
	(0.42)	(0.46)	(0.42)	(0.45)
N	1472	1472	1472	1472
Adjusted R-squared	0.35	0.37	0.43	0.45
Industry dummies (15)	Y	Y	Y	Y
Time dummies (22)	N	N	Y	Y
Region dummies (4)	Y	Y	Y	Y

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 7A Marginal effects

	Disembodied	Embodied	Diff		Disembodied	Embodied	Diff
Period I	0.11	0.07	0.03	**At average**	0.19	0.03	0.16
	(0.03)	(0.03)	(0.03)	**proportion for**	(0.03)	(0.01)	(0.03)
Period II	0.18	0.05	0.08	**At twice**	0.31	0.09	0.22
	(0.02)	(0.02)	(0.02)	**proportion for**	(0.04)	(0.03)	(0.02)
Diff.	0.07	0.02	0.05*	**Diff.**	0.10	0.04	0.06*
	(0.03)	(0.03)	(0.03)		(0.03)	(0.02)	(0.04)

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Table 8 – Multinomial logit regressions of proportion of assignees

	Specification 1		Specification 2	
	MNC	**Domestic firms**	**MNC**	**Domestic firms**
Period I dummy	-2.33 ***	-0.21 ***		
	(0.39)	(0.09)		
Proportion of cases in favor of IP			0.42 ***	0.18 ***
			(0.18)	(0.04)
Log (lagged US univ. patents)	0.41 ***	0.29 ***	0.46 ***	0.31 ***
	(0.08)	(0.06)	(0.14)	(0.10)
Log(lagged US total patents)	0.30 **	0.19 ***	0.36 ***	0.22 ***
	(0.07)	(0.05)	(0.12)	(0.06)
Labor per man hour employed	-0.08 *	-0.28 *	-0.09 *	-0.27 **
	(0.05)	(0.17)	(0.05)	(0.16)
Constant	0.84 **	-1.27 ***	0.71 **	-1.08 ***
	(0.44)	(0.15)	(0.46)	(0.28)
N	6302		6302	
Log likelihood	-2150.96		-2149.67	
Industry dummies (15)	Y		Y	
Time dummies (22)	N		Y	
Region dummies (4)	Y		Y	

Notes: * Sig. at 10% level; ** Sig. at 5% level; ***Sig. at 1% level. Standard errors in parentheses

Appendix -1 - Proof of propositions:
We begin by characterizing the equilibrium and signing the impact of an increase in θ on p and M. We first characterize the slopes of the PP curve TT curve.
Recall that the equilibrium is defined by two equations

$$D(p) = Q\{\beta(1 - F(Y)) + (1-\beta)(1 - F(Z)) + 1 - G(Y)\} \quad \text{(A1)}$$

$$L\gamma\{\beta F(Y) + G(Y)\} = \tau(M)\gamma(1-\beta)(1 - F(Z)) \quad \text{(A2)}$$

where $Y = \frac{L-E}{p-c}$; $Z = \frac{\tau(M)}{p-c}$

The endogenous variables are p and M. Let A_{11}, A_{12} denote the partial derivatives of (A1) with respect to p and M respectively, and likewise A_{21}, A_{22} for (A2).

1. We first show that the PP curve is downward sloping.

   $A_{11} = D'(p) - Q\left\{-\beta dF(Y)\frac{\partial Y}{\partial p} - (1-\beta)dF(Z)\frac{\partial Z}{\partial p} - dG(Y)\frac{\partial Y}{\partial p}\right\} < 0$
   $A_{12} = Q\left\{(1-\beta)dF(Z)\frac{\partial Z}{\partial M}\right\} < 0$
   Thus $\left.\frac{dM}{dp}\right|_{PP} = -\frac{A_{11}}{A_{12}} < 0$
2. We first show that the TT curve is also downward sloping.
   $A_{21} = L\gamma\frac{\partial Y}{\partial p}\left(\beta dF(Y) + dG(Y)\right) + \tau(M)(1-\beta)\gamma dF(Z)\frac{\partial Z}{\partial p} < 0$
   To sign A_{22} we assume that $\frac{f(Z)}{1-F(Z)} < Z$. $\frac{f(Z)}{1-F(Z)}$ is the elasticity of 1-F(Z) w.r.t Z.
   $A_{22} = (1-\beta)\gamma\left\{(1-F(Z))\tau'(M) - \tau(M)dF(Z)\frac{\partial Z}{\partial M}\right\}$
   Since, $\frac{\partial Z}{\partial M} = \frac{\tau'(M)}{p-c}$, $A_{22} = \tau'(M)(1-\beta)\gamma\left\{\frac{1-F(Z)}{dF(Z)} - Z\right\} < 0$
   Thus $\left.\frac{dM}{dp}\right|_{TT} = -\frac{A_{21}}{A_{22}} < 0$

   Stability requires $|H| = A_{11}A_{22} - A_{12}A_{21} > 0$. This also implies that $\frac{A_{11}}{A_{12}} > \frac{A_{21}}{A_{22}}$ which makes the PP curve steeper than the TT curve.

3. We now show that $\frac{dp}{d\theta} < 0$

   Let $A_{1\theta}$ be the partial derivative of (A1) with respect to θ.

   $$A_{1\theta} = Q\frac{\partial Y}{\partial \theta}\{\beta dF(Y) + dG(Y)\} > 0$$

   Note that $\frac{\partial Y}{\partial \theta} = \frac{E(1-\alpha)}{p-c} > 0$

   $$A_{2\theta} = L\gamma\frac{\partial Y}{\partial \theta}\left(\beta dF(Y) + dF(Y)\right) > 0$$

   $$\frac{dp}{d\theta} = \frac{A_{1\theta}A_{22} - A_{2\theta}A_{12}}{|H|}$$

   We need an additional assumption to determine the sign $\frac{dp}{d\theta}$. This is that $Z \geq 1$.

$$\frac{dp}{d\theta} = \gamma Q \tau'(M)(1-\beta)\left[\frac{\partial Y}{\partial \theta}\big(\beta dG(Y) + dG(Y)\big)\right]\left[\frac{1-F(Z)}{f(Z)} - Z - \frac{L}{p-c}\right] < 0$$

4. The proof to show that that $\frac{dp}{d\alpha} < 0$ is similar and hence omitted
5. $\frac{d^2p}{d\alpha d\theta} < 0$
   Note that when α=0, $\frac{\partial Y}{\partial \theta} = 0$, so that $\frac{dp}{d\theta} = 0$.
   But from (3) above, when 0<α≤1, $\frac{dp}{d\theta} < 0$. Thus $\frac{d^2p}{d\alpha d\theta} < 0$.
6. We now show that $\frac{dM}{d\theta} > 0$
   $M = \gamma\{\beta F(Y) + G(Y)\}$
   $$\frac{dM}{d\theta} = \frac{\gamma}{p-c}\left(E(1-\alpha) - \frac{\big(L - E(1-\theta)(1-\alpha)\big)}{(p-c)}\frac{\partial p}{\partial \theta}\right)\{\beta dF(Y) + dG(Y)\} \equiv X\{\beta dF(Y) + dG(Y)\} > 0$$
7. We now show that $\frac{dN}{d\theta} < 0$
   $N = \gamma\{\beta\big(1 - F(Y)\big) + \big(1 - G(Y)\big)\}$
   $$\frac{dN}{d\theta} = \frac{\gamma}{p-c}\left(E(1-\alpha) - \frac{\big(L - E(1-\theta)(1-\alpha)\big)}{(p-c)}\frac{\partial p}{\partial \theta}\right)\{-\beta dF(Y) - dG(Y)\} \equiv X\{-\beta dF(Y) - dG(Y)\}$$
8. We now show that $\frac{d\rho}{d\theta} > 0$
   Recall that ρ=M+λN
   $$\frac{\partial \rho}{\partial \theta} = \frac{\partial M}{\partial \theta} + \lambda\frac{\partial N}{\partial \theta} = X\{\beta dF(Y) + dG(Y)\} - \lambda X\{\beta dF(Y) + dG(Y)\} = (1-\lambda)X\{\beta dF(Y) + dG(Y)\} > 0$$
9. $\frac{d^2\rho}{d\theta d\alpha} > 0$. Note that when α=1, X=0 and both $\frac{dN}{d\theta} = 0$ and $\frac{dM}{d\theta} = 0$ so that $\frac{d\rho}{d\theta} = 0$.
   However, when 0≤α<1, $\frac{d\rho}{d\theta} > 0$ as shown above. Thus $\left.\frac{d\rho}{d\theta}\right|_{0\le\alpha<1} - \left.\frac{d\rho}{d\theta}\right|_{\alpha=1} > 0$. This implies that $\frac{d^2\rho}{d\theta d\alpha} > 0$
10. We now show that $\frac{\partial \Phi_M}{\partial \theta} - \frac{\partial \Phi_D}{\partial \theta}$ >0 is ambiguous and depends on the nature of distribution of G and F. However if x+F(.) =G(.) where x>1, then $\frac{\partial \Phi_M}{\partial \theta} - \frac{\partial \Phi_D}{\partial \theta} > 0$
    $\Phi_M = G(Y) + \lambda(1 - G(Y))$
    $\Phi_D = \beta(F(Y) + \lambda(1 - F(Y))$
    $\frac{\partial \Phi_M}{\partial \theta} = \Big(dG(Y) - \lambda\big(dG(y)\big)\Big)X$ and $\frac{\partial \Phi_M}{\partial \theta} = \Big(dF(Y) - \lambda\big(dF(y)\big)\Big)X$
    $\frac{\partial \Phi_M}{\partial \theta} - \frac{\partial \Phi_D}{\partial \theta} = \big(dG(Y) - \beta dF(Y)\big)(1-\lambda)X$, the sign of which is ambiguous.
    However if the distributions were such that x+F(.) =G(.) where x≤0.
    $$\frac{\partial \Phi_M}{\partial \theta} - \frac{\partial \Phi_D}{\partial \theta} = (1-\beta)dF(Y)(1-\lambda)X > 0$$
11. The proof for $\frac{\partial \Phi_M}{\partial \alpha} - \frac{\partial \Phi_D}{\partial \alpha} > 0$ is very similar to (10) and hence is omitted.
12. $\frac{d^2M}{d\alpha d\theta} > 0$

    Note that when α=0, $\left.\frac{\partial p}{\partial \theta}\right|_{\alpha=0} = \frac{\gamma}{p-c}\big(E(1-\alpha)\big)\{\beta dF(Y) + G(Y)\} < \left.\frac{\partial p}{\partial \theta}\right|_{0<\alpha\le1}$

    Thus $\frac{d^2M}{d\alpha d\theta} > 0$.

13. The proof to show that that $\frac{dM}{d\alpha} > 0$ is similar and hence omitted
14. We now show that license payments, Ω are increasing in θ

    $\Omega = \tau(M)\gamma(1-\beta)\big(1 - F(Z)\big)$.

    At equilibrium, $\tau(M)\gamma(1-\beta)\big(1 - F(Z)\big) = LM$. Thus $\frac{\partial \Omega}{\partial \theta} = L\frac{\partial M}{\partial \theta} > 0$

15. $\frac{d^2\Omega}{d\alpha d\theta} > 0$
    $$\frac{\partial^2 \Omega}{\partial \theta\, \partial \alpha} = L\frac{\partial^2 M}{\partial \theta \partial \alpha} > 0$$

Appendix 2 – Derivation of estimation equation for competition

We intend measuring competition based in HHI calculated at an industry level using revenue. Let q_{ijt} denote the quantity produced and sold by an individual firm where *i* indexes a firm, *j* industry and *t* time (for convenience we drop the region, time and industry subscripts henceforth so that the quanity produced and sold by a firm is just q_i). Let X be the aggregate industry quantity. Likewise let p_i and P be the firm specific and industry price respectively. We assume that firms are price takers so that p_i=P. Our measure of HHI is $h = \sum_{i=1}^{N}\left(\frac{Pq_i}{PX}\right)^2$ or just $\sum_{i=1}^{N}\left(\frac{q_i}{X}\right)^2$ where K is a constant. We can decompose q_i as $\bar{q}$ which is the average quanity produced by a firm in an industry and a firm specific time varying component denoting the capability of a specific firm y. Thus $h = \sum_{i=1}^{N}\left(\frac{\bar{q}+y}{X}\right)^2$ which can be written as $\left(\frac{1}{N}\right)^2 + \sum_{i=1}^{N}\left(\frac{y}{X}\right)^2$. Taking logs, $\log(h) \approx 2\log\left(\frac{1}{N}\right) - 2\log \mathrm{Y}$. Assuming that N is a function of price and marginal costs, $\log(h) \approx \delta_0 + \delta_1\theta + \delta_2\alpha + \delta_3\log(P) + \delta_4 c + \theta_r R + \theta_j J + \theta_t T + \epsilon_{irjt}$

Our theory suggests the expected quantity supplied in an industry, X can written as $X = Q\left\{F\left(1 - \frac{L-E(1-\theta)(1-\alpha)}{p-c}\right) + F\left(1 - \frac{\tau}{p-c}\right)\right\}$. Note that L,p and τ are function of θ and α We write the reduced form version of this equation in log as

$$\log(X) = \gamma_0 + \gamma_1\theta + \gamma_2\alpha + \gamma_3\log(P) + \gamma_4 c + \gamma_r R + \gamma_j J + \gamma_t T + \eta_{rjt} \qquad (1)$$

Note that in (1) above, P is endogenous. We now derive P from a standard simultaneous equation model. While (1) above is the supply side, the demand side of the equation can be written as:

$$\log(X) = \lambda_0 + \lambda_1 \log(P) + \lambda_j J + \lambda_r R + \lambda_t T + u_{rjt} \qquad (2)$$

Thus, c, α and θ act as exclusion restrictions since they appear on the supply side but not on the demand side. This set of structural equations leads to the following reduced form equation for X

$$\log(X) = \kappa_0 + \kappa_1\theta + \kappa_2\alpha + \kappa_3 c + \kappa_j J + \kappa_r R + \kappa_t T + m_{rjt} \qquad (3)$$

where $\kappa_0 \equiv \frac{(\gamma_0-\gamma_3)\lambda_1}{\lambda_1-\gamma_3}; \kappa_1 \equiv \frac{\lambda_1\gamma_1}{\lambda_1-\gamma_3}; \kappa_2 \equiv \frac{\lambda_1\gamma_2}{\lambda_1-\gamma_3}; \kappa_3 \equiv \frac{\lambda_1\gamma_4}{\lambda_1-\gamma_3}; \kappa_R \equiv \frac{(\gamma_r-\gamma_3\lambda_r)\lambda_1}{\lambda_1-\gamma_3}; \kappa_j \equiv \frac{(\gamma_j-\gamma_3\lambda_j)\lambda_1}{\lambda_1-\gamma_3}; \kappa_t \equiv \frac{(\gamma_t-\gamma_3\lambda_t)\lambda_1}{\lambda_1-\gamma_3}; m_{rjt} \equiv \left(\frac{\lambda_1}{\lambda_1-\gamma_3}\right)(\eta_{rjt} - \gamma_3 u_{rjt})$

Also (4)

$$\log(P) = k_0 + k_1\theta + k_2\alpha + k_3 c + k_j J + k_r R + k_t t + \sigma_{rjt}$$

where $k_0 \equiv \frac{\kappa_0-\lambda_0}{\lambda_1}; k_1 \equiv \frac{\kappa_1}{\lambda_1}; k_2 \equiv \frac{\kappa_2}{\lambda_1}; k_3 \equiv \frac{\kappa_3}{\lambda_1}; k_j \equiv \frac{\kappa_j-\lambda_j}{\lambda_1}; k_r \equiv \frac{\kappa_r-\lambda_r}{\lambda_1}; k_t \equiv \frac{\kappa_t-\lambda_t}{\lambda_1}; \sigma_{rjt} \equiv \frac{m_{rjt}-u_{rjt}}{\lambda_1}$

Thus

$$\log(h) = \delta_0 + k_0 + (\delta_1 + k_1)\theta + (\delta_2 + k_2)\alpha + (\delta_4 + k_3)c + (\theta_j + k_j)J + (\theta_r + k_r)R + (\theta_t + k_t)t + v_{rjt} + \sigma_{\mathrm{rjt}} \qquad (5)$$

Or

$$\log(h_{rjt}) = \phi_0 + \phi_1\theta + \phi_2\alpha + \phi_3 c + \phi_j J + \phi_r R + \phi_t t + e_{rjt} \qquad (6)$$

where $\phi_0 \equiv \delta_0 + k_0 + \omega_i; \phi_1 \equiv \delta_1 + k_1; \phi_2 \equiv \delta_2 + k_2; \phi_3 \equiv \delta_3 + k_3; \phi_r \equiv \delta_r + k_r; \phi_j \equiv \delta_j + k_j; \phi_t \equiv \delta_t + k_t$ and $e_{rjt} \equiv v_{rjt} + \sigma_{rjt}$