Do patents shield disclosure or assure exclusivity when transacting technology?

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Abstract

Patents may assist trade in technology either by protecting buyers against the expropriation of the idea by third parties (the appropriation effect) or by enabling sellers to more frankly disclose the idea during the negotiation phase (the disclosure effect). We test for the presence of both these effects using quasi-experimental matching analysis on a novel dataset of 860 technology transaction negotiations. We identify the appropriation effect by comparing the probability of successful-negotiations involving a granted patent with those involving a pending patent. Similarly, we identify the disclosure effect by comparing the probability of successful negotiations involving a pending patent with those involving no patent. We find evidence for the appropriation but not the disclosure effect: technology transaction negotiations involving a granted patent instead of a pending patent are 10 per cent more likely to be successfully completed (compared with an average completion rate of approximately 80 per cent).

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1. Introduction

Trade in technology has become a central part of today's highly-specialized and opened innovation process (Arora, Fosfuri, and Gambardella 2001; Chesbrough 2003). Data from the US National Science Foundation shows that the ratio of US business R&D that was contracted out to external enterprises grew between 1981 and 2007 from about 2 per cent to 7 per cent (NSB, 2008). Technology transactions create gains from trade by allowing the emergence of a class of specialized inventors, which increase innovation quality and speeds development time (Lamoreaux and Sokoloff 2001; Spulber 2008). They have received increased academic attention over the recent years (see Arora and Gambardella 2010 for a survey). Previous research has observed that patent protection facilitates technology transactions (Arora and Ceccagnoli 2006; Branstetter, Fisman, and Foley 2006; Gans, Hsu, and Stern 2008). However, it is silent on the mechanisms through which the effect occurs.

In this paper, we investigate why patents facilitate trade in technology. We empirically test two hypotheses motivated by economic theory. First, patents may increase the appropriability of inventions for the seller. Possession of a valid patent may help assure prospective buyers that their future profits will be protected. Second, patents may encourage sellers to more openly disclose the technology to prospective buyers since the seller has a legal reprisal if the buyer rejects the purchase but tries to exploit the revealed idea. We refer to these two hypotheses as *appropriation effect* and *disclosure effect*, respectively. To the best of our knowledge, these hypotheses have never been confronted with data.

To answer our research question, we apply quasi-experimental matching analysis to novel data on 860 randomly-drawn negotiations to sell or license (simply, to trade) immature technology in Australia. Immature technology, in our study, refers to ideas that need further work in order to be useful or deliver a final product by contrast with mature technologies that are ready-to-use.[1]

To test for the first hypothesis – that patents increase buyers' confidence in their ability to prevent third-party copying – we compared the outcomes of negotiations which, at the time they started, possess a granted patent with negotiations which only possess a pending patent. The treatment group consists of negotiations of technologies with a granted patent and the control group consists of negotiations of technologies with a pending patent. The outcome to be compared is whether or not the negotiations end with a completed transaction. Since applying for a patent implies that the applicant has committed to disclosure, the main difference between the two groups is that the patent-grant group has been granted legal protection against third-party expropriation, while the patent-pending group has been not, ceteris paribus.

To test for the second hypothesis – that patents may (also) act as shields to encourage sellers to disclose their secrets – we compare the outcome of negotiations for technologies subject to a pending patent with the outcome of negotiations for technologies which had never been the subject of a patent application. The treatment group consists of negotiations for patent-pending technologies that have already committed to full disclosure; while the control group consists of negotiations for the never-filed (for patent) technologies. As above, the outcome of interest is whether or not the negotiating parties succeeded in reaching a deal. The logic behind this model is that while neither the pending-patent group nor the never-filed group have assured protection from future expropriation of their profits (were they to continue through to commercialization), the patent-pending group has already committed to

[1] Giuri and Luzzi (2005) provide examples of different markets according to the maturity of the technology traded. See Arora and Gambardella (2010) for more discussion of the different motives for trading mature rather than immature technologies.

full disclosure. By law, a patent document must give enough information to enable a person ‘skilled in the art’ to reproduce the invention.

To anticipate our results, we find evidence that protection for exclusivity aides the transfer of technology but no evidence that patents have a positive effect on negotiations by smoothing the way for frank disclosure. More specifically, we find that a patent grant (compared with a patent application) raises the chance that technology transaction negotiation will be successfully completed by about 10 percentage points (the average completion rate in our sample is approximately 80 per cent).

The rest of the paper is organized as follows. Next section explains how patents may assist technology transactions and states our hypotheses. Section 3 presents the empirical model and section 4 describes the data. The results are presented in section 5, and section 6 concludes.

2. Patents and Trade in Technology

Several types of evidence point to the importance of patents as facilitators in the market for technology. Lamoreaux and Sokoloff (2001) argue that the changes in the US patent law in the 19th century were instrumental in the development of a market for technology. Burhop (2010) documents a well-developed market for patents in Imperial Germany. Branstetter, Fisman, and Foley (2006) show that technology transfer within US multinational firms increases in response to a strengthening of intellectual property (IP) rights in host countries. Arora and Ceccagnoli (2006) find that an increase in the effectiveness of patent protection increases licensing propensity (at least when the firm lacks specialized complementary assets required to commercialize new technologies). Finally, Gans, Hsu, and

Stern (2008) observe that a patent grant increases the probability that a licensing agreement will be achieved. Another stream of research has surveyed the motives to patent and provide additional evidence on the importance of patents in technology transactions (Cohen, Nelson, and Walsh 2000; Blind et al. 2006; de Rassenfosse 2012). These surveys of patenting firms report that between 20 and 30 per cent of respondents take patents in order to generate licensing revenues.

Although these studies establish a clear link between patents and technology transactions, they are not able to identify the reasons for the effect. Patent protection may facilitate technology transactions in two ways: insulate the idea against third-party expropriation (*appropriation effect*); and encourage frank disclosure of the technical details of the idea (*disclosure effect*).

Our first hypothesis relates to the appropriation effect. The idea that patents should be used to prevent third-party expropriation is long-established (see the historical summary in Machlup and Penrose 1950). If firms are not able to recoup the upfront costs of their inventions through some degree of monopoly right, then their commitment to invention and innovation may be below optimal (Arrow 1962). Buyers may rely on patent protection to ensure exclusive use of the invention. Accordingly, we propose:

Hypothesis 1: Patents facilitate technology transaction negotiations (sale or license) by offering protection from third-party expropriation.

If the threat of third-party expropriation is a factor in whether or not a negotiation is completed, then we further expect that a patent grant will have greater effects in technologies where the patent document is more able to codify the knowledge needed to use the idea. The classic areas where codification is (near) complete are the chemical and drug-related technologies (Teece, 1986). Hence, we propose:

Hypothesis 1a: Patents have a greater impact on facilitating technology transaction negotiations from third-party expropriation in the more codified technologies.

For similar reasons, we expect that buyers who wanted an exclusivity clause included in their contract will be more concerned about third-party imitation than those that did not. Accordingly, we propose:

Hypothesis 1b: Patents have a greater impact on facilitating technology transaction negotiations from third-party expropriation when buyers also require an exclusivity clause.

Our second hypothesis relates to the disclosure effect. The idea that it is difficult to sell a good that has no property rights has been discussed over the last half century and is known as the 'paradox of disclosure' (Arrow, 1962). If the value of a piece of knowledge is unknown to the buyer until it is disclosed to her, then she only knows its value when she has acquired the knowledge. Then however, she has no need to buy it.

This issue, which has been well known among IP professional circles for some time, is also discussed within the academic literature.[2] Ordover (1991) and subsequently, Lamoreaux and Sokoloff (2001), Anton and Yao (2003), Gans and Stern (2003), Gans, Hsu, and Stern (2008), OECD (2008) and Kani and Motohashi (2012) have all argued that patents constitute a shelter under which to share information during negotiations. Patents allow the seller to reveal technological information to the buyer while guarding against imitation. According to Gans, Hsu, and Stern (2008, 12) '...patent rights can have a significant impact on the risk of expropriation and the willingness of licensors to disclose unprotected information.' The much celebrated Kearns' case of an intermittent windscreen wiper is the archetypical example of second-party expropriation. The inventor, Robert Kearns, disclosed

[2] The issue regularly appears among the advice offered to firms by patent attorneys (see, for example, Glazier 1997, 77).

the idea to Ford Motor Company and Chrysler Corporation in a bid to license the technology. Although the offer was rejected, Kearns found out afterward that Ford and Chrysler had installed intermittent wipers in their cars (Seabrook 2008).

The idea that patents are needed to disclose information is not without its detractors. According to Anton and Yao (1994), a prospective seller can appropriate sizeable profits absent patent protection by threatening to reveal the technology to 'all' if the prospective buyer breaches confidentiality. 'Revealing all' places the knowledge in the public arena and effectively undermines the expropriator's monopoly position. However, this strategy is quite uncertain and it is not clear that such scorched-earth threats pay-off. Others have suggested that confidentiality agreements to bind prospective buyers to not use the disclosed knowledge can be an alternative to patents. It is difficult to get hard data on the extent to which confidentiality agreements are used in transacting technology. Some legal practitioners report that prospective R&D-active buyers will not sign these agreements since they could be concurrently developing similar ideas in-house and would not wish to sign away unspecified rights (see also Merges 2005; Sichelman and Graham 2010). Sichelman and Graham (2010) also argue that confidentiality agreements are difficult and expensive to prove and Cheung (1982) claims that US firms usually require outside inventors to sign a waiver acknowledging that no confidential relationship has been established. Given this, we propose:

Hypothesis 2: Patents facilitate technology transactions by enabling disclosure.

We further expect that the paradox of disclosure creates greatest difficulties for negotiations where there is no need for ongoing inventor contributions during development and commercialization. The requirement for ongoing inventor participation usually means that while one can describe how the idea works on paper, it is unlikely to be fully operational or operational in a cost effective way, without the tacit knowledge acquired trough experiment and use. If the buyer cannot achieve full value without the cooperation of the seller, they will be less likely to expropriate the idea. In transactions without the requirement for ongoing inventor involvement, we would expect the fear of second-party expropriation to be greater and selling parties will accordingly be more reticent about how much they reveal ceteris paribus. If full and frank disclosure is an important determinant of completed negotiations, then we would expect to see higher completion rates in deals where a patent exists (full disclosure being made) and there is ongoing inventor participation than in deals where there is no patent (no evidence of full disclosure) and also no need for ongoing inventor participation. Given this, we suggest:

Hypothesis 2a: Patents will have a greater impact on facilitating technology transactions through disclosure if there is no requirement for ongoing inventor participation.

3. The Model

This section discusses how we test our hypotheses while taking into account the possible endogeneity of patent protection status.

3.1. Endogeneity in Patent Status

To test for the appropriation effect we limit our sample to negotiations of technologies that held either a granted or pending patent at the time of negotiations. Since, in this sample, all features of the technologies are, or will be disclosed by the corresponding patent applications, the main difference between the two groups of negotiations is the degree of legal certainty over the negotiated technology (that is, whether or not it has been granted a patent).[3] We model the probability of a negotiation to be completed instead of abandoned as:

$$Y_i = a_0 + a_1 G_i + \boldsymbol{X}_i' \boldsymbol{a_2} + \boldsymbol{Z}_i' \boldsymbol{a_3} + \varepsilon_i \quad (1)$$

where, for each negotiation i, $Y_i = 1$ if that negotiation concludes in a deal and 0 otherwise; $G_i = 1$ if, at the time of negotiations, the technology under consideration was the subject of a granted patent and 0 if the technology was the subject of only a *pending patent*; $\boldsymbol{X}_i$ refers to observed factors that affect Y_i but are uncorrelated with G_i; $\boldsymbol{Z}_i$ refers to observed factors that affect both Y_i and G_i; and ε_i is an unobserved, independently and identically distributed random error term uncorrelated with $\boldsymbol{X}_i$ and $\boldsymbol{Z}_i$, that is, ε_i reflects the presence of random unmeasured factors affecting Y_i.

The coefficient of interest in equation (1) is a_1, which reflects the contribution that having a certain legal title has on buyers' perception of third-party expropriation and thus on the outcome of the negotiation. All else equal, if patent protection for exclusivity is important, then the probability for the negotiation to be completed increases with G_i (that is, $a_1 > 0$). However, the vector $\boldsymbol{Z}_i$, which include factors that affect both Y_i and G_i, is of most concern to the estimation of a_1. This vector includes any factor that would encourage the seller to begin negotiations before the patent is granted and also that affects the success of the negotiations. Anecdotally, we know that some parties seek to negotiate before the patent has

[3] While the possibility exists that granted patents become later revoked, post-grant challenges to validity are very rare. Lemley and Shapiro (2005) estimate that 0.1 per cent of U.S. patents are litigated to trial. In addition, a patented technology may become more attractive to prospective buyer than a non-patented one if the patent can be used as a blocking patent. Our test would not be able to distinguish these possible uses of patent from the use we discussed above. However, in all cases patent provides protection to the 'exclusive' use of the patented technology.

been granted while others wait until the legal uncertainty has been resolved. These factors may include the speed of technological change in the relevant area or the motivations of the parties. Some technologies, and perhaps some types of applicants, are more likely to enter negotiations when they only have a pending patent perhaps because they see the need to transact as more urgent. Alternatively, the patent grant may affect the probability that negotiations are completed because the potential buyers regard the grant as an indicator of technological feasibility. Even though the patent is not assessed on its technological feasibility during examination, a grant may influence the market's perception of its technological feasibility. As such, the perception of technological feasibility will also form one of the $\boldsymbol{Z}_i$ variables resulting in a biased estimate of a_1.

To test for the disclosure effect we exclude transactions that had a granted patent, and split the remaining sample into two groups: transactions that had filed for a patent and had thus committed to full disclosure and those that had not. [4] Regardless of the reason why a patent has not been sought (early-stage research, not patentable subject matter, cost, non-obviousness or desire for secrecy), the owners of the technologies have a choice of how much of the technology to reveal during negotiations and we can assume that, on average, how much they reveal is no more, but rather less, than the pending-patent group. Similar to equation (1), we model the probability of a complete negotiation as:

$$Y_i = b_0 + b_1 P_i + \boldsymbol{V}_i' \boldsymbol{b_2} + \boldsymbol{W}_i' \boldsymbol{b_3} + \epsilon_i \qquad (2)$$

[4] All jurisdictions in the world, bar the United States, disclose the contents of the patent application 18 months after filing. In the United States, since 2001, the patent application is disclosed only if there is a family application in another jurisdiction. A seller can potentially withdraw its application before the 18 month publication date and prevent disclosure but this is rare. The number of applications withdrawn each year from IP Australia is extremely small (less than 20 out of about 30,000 applications).

where $Y_i = 1$ if negotiations conclude in a deal and 0 otherwise; $P_i = 1$ if, at the time of negotiations, the technology was the subject of a *pending patent* and 0 if the seller of the technology had *not filed for a patent*; $\boldsymbol{V}_i$ refers to factors that affect Y_i but are uncorrelated with P_i; $\boldsymbol{W}_i$ refers to factors that affect both Y_i and P_i; and ϵ_i is a random error term uncorrelated with the covariates.[5]

As before, the coefficient of interest in equation (2) is b_1 which reflects the contribution that greater disclosure has on whether negotiations are completed. Also, it is the factors that affect both Y_i and P_i (vector $\boldsymbol{W}_i$) that present us with a problem in obtaining an unbiased estimate of b_1. The vector $\boldsymbol{W}$ includes factors that lead parties to seek patent protection in the first place, such as whether the idea is patentable subject matter, the desire for secrecy, stage of the technology, the size of the inventive step and the financial resources of the technology owner.

3.2. Econometric Method: Exact Matching

Given the potential endogeneity problems discussed above, we apply a non-parametric, quasi-experimental matching method to obtain unbiased estimates of a_1 and b_1.[6] Our estimates of a_1 and $b_1$in equation (1) and (2) are the estimated Average Treatment effects on the Treated (*ATT*) after pre-processing the sample using exact matching analysis (Iacus, King, and Porro, 2012a and 2012b).[7] If Y^1 is the set of completed negotiations with

[5] Note that the group of pending patents also includes one observation with a refused patent. Henceforth we simply refer to the 'pending group'.

[6] An alternative approach is to use instruments for *G* and *P* and estimate equations (1) and (2) using the instrumental variable regression approach. We could not do this because we do not have any appropriate instrument.

[7] See Azoulay et al. (2010) and Groves and Rogers (2011) for recent applications of the method.

treatment, G or P, and Y^0 is the set of completed negotiations of same group if they did not have this treatment, then:

$$ATT_i = E[Y_i^1 - Y_i^0 \mid G \text{ or } P = 1] \tag{3}$$

where i is the unit of analysis, in our case, technology transaction negotiation. As discussed above, while our data set is randomized with respect to negotiation completion status, we cannot be sure that it is random with respect to selection into the treatment (G or P). If the factors that cause selection into treatments G or P also influence the outcome, Y, then the estimated ATT will be biased. If selection the values of $\boldsymbol{Z}_i$ differ systematically across G_i (unbalanced), then we need to pre-process the sample to ensure that the observations are balanced (that is, the treated and the control (untreated) samples are similar in terms of $\boldsymbol{Z}_i$ or $\boldsymbol{W}_i$) before the ATT is estimated.

Cochran (1968) proposed reducing this selection bias in the estimate of ATT by dividing the sample into homogenous sub-groups (or strata) and then making a strata-by-strata comparison of the treatment and control populations. In this way, the dataset mimics a random assignment dataset. This provides us with unbiased estimates of ATT if we have adequate observable variables on factors which cause treatment and the outcome (the Z and W variables).[8]

Because our question asks about the status of IP protection *at the time the negotiations started*, treatment assignment is strongly ignorable given the observed covariates (that is, does not depend on the potential outcome), and we can assume that treatment assignment is also ignorable given the matching on homogenous strata. The relevant

[8] Similar to other matching methods, exact matching is not able to control for selection based on unobservable factors. It is thus important to include all observed relevant factors in $\boldsymbol{Z}$ and $\boldsymbol{W}$. Iacus, King and Porro (2012a and 2012b) provide comparisons of the exact matching method and other types of matching procedures.

covariates to identify each strata are those that determine both treatment assignment and the outcome but are not affected by treatment assignment or outcome. We discard treatment observations without a matching control observation in their strata. Imposing this common support condition in the estimation of the propensity score improves the quality of the matches used to estimate the *ATT*.

As discussed, there are two treatment effects of interest: the patent grant, G, which proxies for the appropriation effect, and the patent pending status, P, which proxies for the disclosure effect. To test for whether the patent affects negotiation success via its effect on preventing third-party expropriation, in each strata, we compare the negotiation success rate of treatment recipients (transactions involving technologies with a patent) with the success rate of patent-pending transactions. Thus,

$$ATT = \frac{1}{n}\sum_n (Y_i^1 - Y_i^0) \tag{4}$$

where Y^1 is the completion status of transactions involving technologies with patent, Y^0 is the completion status of transactions of technologies with a pending patent with matching Z values, and n is the size of the matched sample. The test for whether the patent affects negotiation success via its effect on disclosure is a parallel case. It involves in each strata comparing the negotiation success rate of transactions involving technologies with a pending patent with the success rate of technologies which have never been the subject of a patent application.[9]

[9] All coarsened exact matching analyses were performed using the 'cem' command in STATA developed by the authors of Iacus, King and Porro (2012a).

4. Data

4.1. Survey of Australian Technology Traders

We use data drawn from a 2011 survey of Australian technology traders. In order to prepare the survey we conducted 66 semi-structured interviews around Australia during 2010. This allowed us to identify the types of individuals and organizations that may participate in Australian technology market as well as to identify key variables to collect from the survey. The final list of potential traders, which comprised both in-house business development managers and independent go-betweens, was surveyed in early 2011 by mail. The population includes 1427 people who we believed had a hands-on role in technology transactions (we excluded managers with only supervisory or policy roles). Effectively, everyone on the population list we constructed was sent a questionnaire. We asked each survey participant about the last completed and the last abandoned negotiation. Doing this ensured that the collected data are random with respect to the outcomes and the characteristics of the negotiation.

The overall response rate was 47.0 per cent, which is high for a company-based survey and reflects the provision of an incentive in the first mail-out (a A$50 gift voucher).[10] The response rates vary from 31.6 per cent for business angels to 65.0 per cent for public sector research organizations. While 670 people responded to the survey, 214 indicated that they had not been involved in a technology transaction with their current employer, leaving 456 people. The final data set consisted of 467 successful and 393 unsuccessful transactions

[10] Approximately 2 per cent of contacts were not 'in scope' as their contact address had changed or the person replied that they were not involved in technology transactions. Other company surveys, which do not include in-the-hand incentives, typically achieve response rates of 10-15 per cent.

(= 860) of which 68 per cent occurred between 2009 and 2011.[11] We do not believe that there is any important non-response bias at our unit of analysis (that is, negotiation) since most respondents reported a pair of their last completed and abandoned negotiation.

As mentioned, our survey only included immature technologies, that is, those that required additional development work before it can be used in production. In the survey, we defined a technology transaction as: 'A non-commercial ready technology that is exchanged between organizations for further development. Exclude transactions between parents and subsidiaries. Exclude MTAs'. A 'successful negotiation' is one where the respondent described the transaction as completed, whereas an unsuccessful transactions are negotiations that were not described as completed and had not concluded after 12 months.

For each transaction, we asked traders a series of categorical multi-response questions. The first question was about the technology area which we categorize three ways as (1) biotech, chemicals, drugs & medical; (2) software and (3) electronic, mechanical and other. The second was about how commercial-ready the technology was when negotiations began and this was categorised as (1) basic or applied science, and (2) proof of concept, prototype, manufacturing pilot stage or none of the above. We also asked about the type of formal IP the technology possessed at the time of negotiations and categorized these variables as (1) patent pending, (2) registered patent, (3) copyright and (4) none of the above. In addition, we were able to code the respondent according to their sector of employment. We categorized this as a binary variable (1) industry and (2) government, patent attorney, university or public research institute.

[11] Since some industry brokers were asked about their last successful and unsuccessful technology acquisition and sale, it is possible to have multiple responses per broker.

We asked respondents a series of questions about the uncertainty of the technology including 'how uncertain the technical feasibility of the technology was' and asked them to rate this on a Likert scale with the anchors 1='very certain' and 7='very uncertain'. We asked respondents to indicate whether the signed or proposed contract included exclusivity clauses and whether it required ongoing inventor participation.

4.2. Data Descriptives

Table 1 presents the mean values for the data partitioned by IP status at the time of negotiations: those with a granted patent; those with a pending patent but no granted patent; those with neither a granted or pending patent but copyright protection and the remainder with none of these options. It shows that whether or not the transaction was completed was clearly and significantly related to IP status. Negotiations where a granted patent was involved have a completion rate of 59.7 per cent compared with 49.0 for the pending-patent group, 69.5 per cent for the copyright-only group and 48.1 per cent for those with neither of these options.

There are also marked differences with respect to the background characteristics. The second row in Table 1 shows that the classically-codified areas of biotechnology, chemicals, drugs & medical, were over-represented (at 66.1 and 62.3 per cent respectively) in the granted and pending patent groups. However, many of these classically-codified technologies were either not patentable or were not thought to need a patent. Some 17.1 per cent of copyright-protected technologies were in the biotechnology, chemicals, drugs & medical technologies as were 48.7 per cent of technologies with no formal IP. An almost mirror image pattern was found for software technologies: they dominated the copyrighted technology area and were relatively scarce in the patent-grant and patent-pending samples. Other points to note are that technologies at the basic or applied science stage were mainly found in the pending-patent group and much less so in the copyright-only group. Negotiations involving an industry (private sector) party were mainly found in the patent-grant and no-formal-IP groups.

With respect to the respondents' perception of the technological feasibility of the idea, those with a granted patent were slightly more likely to consider the technology feasible and those with a pending patent were more likely to consider the technology a risk. This however, may be related to the latter's earlier stage of development when negotiations were conducted (as noted above). While there was no statistical difference in whether exclusivity clauses were included in (potential) contracts across groups, the patent-pending group was most likely to require ongoing inventor participation. Again, this may be related to the less mature stage of development.

One notable difference across the four IP status groups is the high negotiation completion rate of technologies that are only covered by copyright. Part of this apparent success could be due to their particular nexus with software – 63.4 per cent embodied a software technology (cf. 20.0 overall) – and their lower degree of felt uncertainty about it technical feasibility – 2.8 on the Likert scale (cf. 3.6 overall).

With respect to the granted and pending-patent groups, there is limited difference in the technological composition but a marked difference in the type of respondent and degree of uncertainty over the feasibility of the technology. Negotiations with a granted patent were more likely to involve an industry party and were also rated as more technologically certain. This difference in the perceptions of technical feasibility may be due either to the effect of the patent grant decision acting as the imprimatur of quality or because sellers with more technically risky ideas tend to negotiate early in the patent lifecycle. To control for both these possibilities, we will include our measure of the uncertainty of the technical feasibility as a matching covariate (*Z* variable).

*** INSERT TABLE 1 ABOUT HERE ***

5. Econometric Results

5.1. Testing for the Appropriation Effect (Third-Party Expropriation)

Critical to the caliber of our estimates is having measures of factors that affect both selection into treatment and the outcome, that is, our ***Z*** variables. We need to capture any systematic factor that might cause parties to want to enter negotiations earlier rather than later, such as how fast the technology is moving or the normal practices in their organization. It is possible, especially given the descriptive material in Table 1 that these are related to the technology area, the stage of development of the technology and type of organization involved in the transaction. Accordingly, we include our technology area variables, stage of development and respondent sector in our first-stage matching equation using the exact matching technique. In addition, because the grant may be viewed as an indication of the technical feasibility of the technology, we also include a Likert-scale variable which measures the respondent's assessment of the uncertainty surrounding the technological feasibility of the technology.

Table 2 presents the results from matching on the sample of granted and pending patent transactions. The first row, which is a simple comparison of the probabilities of completion, indicates that transactions with a granted patent are 10.8 percentage points more likely to end in a deal than those with only a pending patent. If we compare transactions matched on our ***Z*** variables, we find that this difference falls slightly to 9.7 percentage points but is still significant at the 5 per cent level, confirming Hypothesis 1. Because we match exactly on a limited set of binary or Likert-scale values, we are able to eliminate all differences between the confounding variables between the treatment and control groups. Hence, where we include all the covariates in the matching method, the mean standardized bias (MSB) is zero. The remaining rows test the sensitivity of this *ATT* estimate to exclusion of different matching variables. Both the size and significance of the *ATT* is reduced if we exclude the technology area variables from the identification of the strata.

*** INSERT TABLE 2 ABOUT HERE ***

The results from testing hypotheses 1a and 1b are given in Tables 3 and 4, respectively. Recall that these are estimates of the *ATT* if we limit the sample (a) to technologies in the areas of biotech, chemicals, drugs & medical and (b) to transactions where the proposed contract included exclusivity clauses. We expect that a grant will convey more protection from third-party expropriation in technologies where the use is easily codified in written document. Hence, if patents are primarily used to protect against third-party expropriation (rather than, say, as a signal of quality) we would expect that the *ATT* is stronger under (a) than the sample containing all technologies. For similar reasons, we expect that buyers who wanted an exclusivity clause included in their contract will be more concerned about third-party imitation than those that do not. Over and above this, because in both (a) and (b) we are using smaller samples, it will be harder to achieve significant results, and in this respect, these subsamples are a strong test of the hypothesis.

The results from (a) the codified technologies only sample, presented in Table 3, support the hypothesis that value of the granted patent lies in its ability to protect against third-party expropriation. The *ATT* rises to 14.3 percentage points and this estimate is quite robust to the exclusion of different matching covariates. The estimates from (b) are less clear. While the point estimate is greater (12.8 percentage points) it is only significant at the 10 per cent level which is quite possibly due to the smaller number of observations. Hence we find support for Hypothesis 1 and 1a and qualified support for Hypothesis 1b. We now turn to the tests of the disclosure effect.

*** INSERT TABLE 3 ABOUT HERE ***

*** INSERT TABLE 4 ABOUT HERE ***

5.2. Testing for the Disclosure Effect

Constructing an artificial counterfactual for the pending group from the not-filed group is more difficult since there are presumably more differences between the technologies and motivations of the parties. As such, the strength of our test is weaker than that for third-party expropriation. Our issue is that we need to capture any systematic factor that causes parties to not file for a patent – such as the desire for secrecy, stage of the technology, the small inventive step embodied in the idea or the financial resources of the technology owner – that may also impact on the success of the negotiations. Accordingly, we include our technology variables, stage of development variable, and respondent sector variable (all as defined above) in our first-stage matching equation using the exact matching technique. In addition we include a dummy variable to indicate whether the technology had copyright protection since its presence may indicate a qualitative difference in the technology. Table 5 presents the results from the comparison between the treatment (patent pending) and control groups (never filed) first when unmatched, and then when matched on the set of covariates listed above. The point estimate of the ATT is -0.9 and is not significantly different from zero. As before, we test for the sensitivity of the results to the exclusion of some of these covariates. It is quite clear that having decided to fully disclose (under the cloak of possible patent protection), does not confer any advantage on the proceedings, thereby rejecting Hypothesis 2.

*** INSERT TABLE 5 ABOUT HERE ***

As a robustness test, we examine whether excluding software technologies had any effect on the results. Because it is easier to sell the functionality of software technologies without revealing the source code, the difference in disclosure behavior encouraged by the patent system should be considerably smaller for software technologies compared with other technologies. Table 6 presents the same set of estimations after we have excluded the software only technologies from the sample. Again, the results show very little difference between the ATT estimates.

*** INSERT TABLE 6 ABOUT HERE ***

Finally, we construct a subsample that only included technologies where there were *no* requirements for ongoing inventor participation (in addition to excluding software only technologies) in order to test Hypothesis 2a. We would expect this group of sellers to have the most extreme concerns about disclosing too much information. The requirement for ongoing inventor participation usually means that there is critical information about the technology that is only acquired through use and experimentation. Table 7 shows that that the size of the advantage of having a pending patent is negative and not statistically significant. In other words, the data do not support Hypothesis 2a.

*** INSERT TABLE 7 ABOUT HERE ***

A non-significant effect between treatments and controls allows us to unambiguously reject the presence of a disclosure effect. Indeed, had we observed a higher success rate for the group of pending patents, we would have difficulty interpreting that the higher success rate were due to the disclosure effect and not to an 'expected grant' effect. However, since we find no effect, and we know from the first test that patent grant has a positive effect, we can confidently conclude that disclosure through the patent document does not facilitate technology transactions.

6. Discussion

While both economists and legal scholars have argued that patents operate to facilitate transactions in the market for technology, we know very little about the mechanisms through which this occurs. In this paper, we explicitly test whether this effect operates by strengthening appropriability of the invention or by enabling greater disclosure. Our research question is: do patents enhance the exchange of technology because they augment buyers' confidence in their ability to appropriate future profits or because they encourage sellers to more frankly disclose their technological secrets? We use primary data on 860 completed and abandoned technology transaction negotiations to assess which effect is present. We find supporting evidence that patents facilitate negotiations by their effect on appropriability but no evidence that they facilitate negotiations through disclosure. The latter finding may arise because markets are small enough for reputation to prevent unconscionable behavior or because confidentiality agreements are used when disclosure is an issue (although we note that there is some skepticism on the prevalence of these agreements).

It is possible to think of alternative explanations for our results, and these must be briefly discussed. Regarding the significant impact of a patent grant on the likelihood of completing a transaction, one could argue that the patent office approval 'certifies' the technology, which increases buyer confidence and makes it more likely that a deal will be reached. We have tried to rule out this possibility by explicitly controlling for a measure of technical feasibility. Our second hypothesis associates the disclosure of patent document as enabling a greater sharing of technical information while preserving against the threat of expropriation. An alternative benefit of disclosure is to better define the boundaries of the technology being transacted. These concepts are closely related. However, neither benefit appears to matter because we observe no role of the disclosure of technical information on the likelihood of a completed transaction.

These findings have clear implications for patent offices and attorneys advising clients. Many observers of the patent system report considerable backlogs and lengthy grant delays in major patent offices. Our results suggest that these delays are likely to slow down the pace of technology transfers. This issue is particularly problematic for start-ups and SMEs that are less able to sustain regulatory delays. In this context, the recent implementation of a fast-track option at the USPTO, whereby a patent application enjoys an expedited review in exchange of an additional fee, is particularly welcome. The results also underline the importance of high-quality patent systems. Our results suggest that prospective buyers do care about the threat of third-party expropriation, and a high quality examination is likely to increase buyers' confidence that their future profits will be protected. Thus, a high-quality patent system is essential to a proper functioning of markets for technology.

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Table 1

CHARACTERISTICS OF TRANSACTIONS PARTITIONED BY IP STATUS (MUTUALLY EXCLUSIVE & EXHAUSTIVE)

	GRANTED PATENT		PENDING PATENT		COPYRIGHT ONLY		NO FORMAL IP		ALL
	N=283		N=337		N=82		N=158		N=860
Completed (%)	59.7	*	49.0	*	69.5	**	48.1	+	54.3
Technology area (%)									
Biotech, chemicals, drugs & medical	66.1	**	62.3	**	17.1	**	48.7	*	56.7
Software	13.1	**	14.5	**	63.4	**	21.5		20.3
Other	20.8		23.2		19.5		29.8		23.3
Basic & applied science (%)	23.3		30.3	*	13.4	**	31.0		26.5
Industry party involved (%)	59.4	**	34.1	**	51.2		65.2	**	49.8
Uncertainty of technical feasibility (Likert)	3.4	**	4.0	**	2.8	**	3.5		3.6
Contract included... (%)									
Exclusivity clause	47.3		51.0		51.2		41.1	+	48.0
Ongoing inventor participation	37.5		43.3	**	32.9		30.4	*	38.0

NOTE. — `Likert` indicates a Likert scale variable with anchors 1=’very certain’ and 7=’very uncertain’. Test of significance of the difference between the mean for that IP status group and all other IP status groups combined.

+ p < .10.

* p < .05.

* p < .01.

Table 2

AVERAGE TREATMENT EFFECT ON THE TREATED (GRANTED PATENT VERSUS PENDING PATENT)

COVARIATES (Z)	PROBABILITY OF SUCCESSFUL NEGOTIATION					MSB	N TREATED	N CONTROL
	Coefficient Treated	Coefficient Control	Difference	S.E.	t-stat			
No matching	59.7	49.0	10.8 **	4.0	2.69	15.7	283	337
All covariates	59.1	49.5	9.7 *	4.9	1.97	0.0	257	337
Excluding technology area	59.7	53.0	6.7	4.6	1.43	0.0	273	337
Excluding technology area and development stage	59.7	52.2	7.5 +	4.6	1.66	5.6	283	337

NOTE. — 'All covariates' includes two technology area dummy variables, one stage of development dummy variable, one industry sector dummy variable and one ordinal variable to indicate the degree of felt uncertainty about the feasibility of the technology. Estimation for Kernel matching reported. MBS stands for 'Mean Standardized Bias'.

+ p < .10.

* p < .05.

* p < .01.

Table 3

AVERAGE TREATMENT EFFECT ON THE TREATED (GRANTED PATENT VERSUS PENDING PATENT) – ONLY INCLUDES BIOTECH, CHEMICALS, DRUGS & MEDICAL

COVARIATES (Z)	PROBABILITY OF SUCCESSFUL NEGOTIATION					MSB	N TREATED	N CONTROL
	Coefficient Treated	Coefficient Control	Difference	S.E.	t-stat			
No matching	60.4	46.7	13.8 **	5.0	2.76	34.5	187	210
All covariates	60.1	45.8	14.3 *	6.2	2.32	0.0	173	210
Excluding technology area	60.6	47.5	13.1 *	6.0	2.16	0.0	180	210
Excluding technology area and development stage	60.4	48.7	11.8 *	5.9	2.00	0.2	187	210

NOTE. — 'All covariates' includes two technology area dummy variables, one stage of development dummy variable, one industry sector dummy variable and one ordinal variable to indicate the degree of felt uncertainty about the feasibility of the technology. Estimation for Kernel matching reported. MBS stands for 'Mean Standardized Bias'.

$^{+}$ p < .10.

* p < .05.

* p < .01.

Table 4

AVERAGE TREATMENT EFFECT ON THE TREATED (GRANTED PATENT VERSUS PENDING PATENT) – ONLY INCLUDES NEGOTIATIONS WHERE (PROPOSED) CONTRACT HAD AN EXCLUSIVITY CLAUSE

COVARIATES (Z)	PROBABILITY OF SUCCESSFUL NEGOTIATION						MSB	N TREATED	N CONTROL
	Coefficient Treated	Coefficient Control	Difference		S.E.	t-stat			
No matching	61.9	50.0	11.9	*	5.7	2.09	14.8	134	172
All covariates	62.4	49.6	12.8	+	7.6	1.69	0.0	117	172
Excluding technology area	61.9	50.5	11.4	+	6.6	1.72	0.0	126	172
Excluding technology area and development stage	61.9	51.1	10.9	+	6.5	1.68	5.1	134	172

NOTE. — 'All covariates' includes two technology area dummy variables, one stage of development dummy variable, one industry sector dummy variable and one ordinal variable to indicate the degree of felt uncertainty about the feasibility of the technology. Estimation for Kernel matching reported. MBS stands for 'Mean Standardized Bias'.

$^{+}$ p < .10.

* p < .05.

* p < .01.

Table 5

AVERAGE TREATMENT EFFECT ON THE TREATED (PENDING PATENT VERSUS NO PATENT)

COVARIATES (W)	PROBABILITY OF SUCCESSFUL NEGOTIATION					MSB	N	N
	Coefficient Treated	Coefficient Control	Difference	S.E.	t-stat		TREATED	CONTROL
No matching	49.0	55.5	-6.5	4.2	-1.54	43.9	332	238
All covariates	48.5	49.4	-0.9	5.5	-0.17	4.5	332	238
Excluding technology area	49.0	49.3	-0.3	5.2	-0.06	0.0	339	238
Excluding technology area and development stage	49.0	49.5	-0.5	5.2	-0.10	0.0	339	238

NOTE. — 'All covariates' includes two technology area dummy variables, one stage of development dummy variable, one industry sector dummy variable and one dummy variable to indicate whether copyright protection exists. Estimation for Kernel matching reported. MBS stands for 'Mean Standardized Bias'. The differences are not significantly different from 0.

Table 6

AVERAGE TREATMENT EFFECT ON THE TREATED (PENDING PATENT VERSUS NO PATENT) – EXCLUDES SOFTWARE-ONLY TECHNOLOGIES

COVARIATES (W)	PROBABILITY OF SUCCESSFUL NEGOTIATION					MSB	N	N
	Coefficient Treated	Coefficient Control	Difference	S.E.	t-stat		TREATED	CONTROL
No matching	48.5	51.5	-2.9	4.8	-0.61	33.6	302	171
All covariates	48.0	48.6	-0.6	6.0	-0.10	4.9	302	171
Excluding technology area	48.5	48.3	0.3	5.8	0.05	0.0	309	171
Excluding technology area and development stage	48.5	48.4	0.1	5.8	0.02	0.0	309	171

NOTE. — 'All covariates' includes two technology area dummy variables, one stage of development dummy variable, one industry sector dummy variable and one dummy variable to indicate whether copyright protection exists. Estimation for Kernel matching reported. MBS stands for 'Mean Standardized Bias'. The differences are not significantly different from 0.

Table 7

AVERAGE TREATMENT EFFECT ON THE TREATED (PENDING PATENT VERSUS NO PATENT) – EXCLUDES SOFTWARE-ONLY TECHNOLOGIES AND CONTRACTS REQUIRING ONGOING INVENTOR PARTICIPATION

COVARIATES (W)	PROBABILITY OF SUCCESSFUL NEGOTIATION					MSB	N TREATED	N CONTROL
	Coefficient Treated	Coefficient Control	Difference	S.E.	t-stat			
No matching	45.4	52.8	-7.4	5.9	-1.26	33.0	174	123
All covariates	45.1	53.9	-8.8	7.4	-1.20	0.0	174	123
Excluding technology area	45.4	52.0	-6.6	7.2	-0.91	0.0	174	123
Excluding technology area and development stage	45.4	51.6	-6.2	7.1	-0.88	0.0	174	123

NOTE. — 'All covariates' includes two technology area dummy variables, one stage of development dummy variable, one industry sector dummy variable and one dummy variable to indicate whether copyright protection exists. Estimation for Kernel matching reported. MBS stands for 'Mean Standardized Bias'. The differences are not significantly different from 0.