Trading and Enforcing Patent Rights

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Abstract

Conventional wisdom associates the licensing and sale of patents with comparative advantages in manufacturing or marketing. This view implies that the gains from trade should increase the likelihood of litigation of traded patents. We identify a new source of gains from trade, comparative advantage in patent enforcement, and show that this mechanism reduces patent litigation. Using data on trade and litigation of individually-owned patents in the United States, and exploiting variation in capital gains tax rates we identify the causal effect of trade on litigation. We show that taxation strongly affects patent trading, and that reallocation of patent rights reduces litigation, on average. However, we show that the impact of trade is heterogeneous and that it depends on the characteristics of the transactions, in particular, the patent portfolio size of the buyer and technological fit of the patent in that portfolio.

Keywords: patents, litigation, market for innovation, capital gains taxation.

JEL Codes: K41, H24, O32, O34.

1 Introduction

The "market for innovation" – the licensing and sale of patents – is an important source of R&D incentives, especially for small firms, and individual inventors, for whom patents are often their critical asset. Moreover, transactions in patent rights are important to the development of efficient market structures in high-technology sectors. This is because they shape the division of labor, and the nature of competition, between small firms (or individuals) who specialize in innovation, but lack the capacity for large scale development, production and marketing, and large firms whose comparative advantage may lie in the commercialisation of these inventions (Gans, Hsu and Stern, 2002).

In this paper we investigate the impact of the market for technology on patent enforcement. The costs associated with enforcing patent rights can dilute the innovation incentives patents are designed to provide. Lerner (1995) provides evidence of this 'innovation tax' by showing that small biotechnology firms avoid R&D areas where the threat of litigation is high. Lanjouw and Lerner (2002) show that the risk of preliminary injunctions against infringers can discourage R&D by small firms.

Previous research has typically associated the gains from trade in the market for innovation with vertical specialization (Teece, 1986 and Rosenberg, 1996) and comparative advantages in manufacturing or marketing (Arora and Ceccagnoli, 2006). By raising the potential profit from the innovations, these mechanisms imply that market reallocation of patent rights should increase the likelihood of litigation. In this paper we identify a novel source of private, and social, gains from trade – comparative advantages in patent enforcement. The market for innovation can reduce litigation if it reallocates patents to entities that are more effective at resolving disputes over these rights without resorting to the courts. We provide a simple model to illustrate these two conceptually distinct sources of gains from trade and their impact on litigation. The main focus of the paper, however, is to identify empirically the impact of trade on litigation, and to assess the relative importance of the comparative advantages in commercialisation and enforcement of patent rights. To do so, we construct a new, comprehensive data set that matches information on trades (Serrano, 2010) and litigation (Lanjouw and Schankerman 2001a, 2001b, 2004) involving patents owned by individual inventors in the United States during the period 1983-2000.

Studying how the market reallocation of patent rights affects litigation is challenging because the decision to trade a patent is endogenous. To address this concern, we exploit a provision in the U.S. tax law that allows us to use variation in capital gains tax rates across states and over time as an instrumental variable to identify the causal effect of a change in patent ownership on litigation. Under U.S. law, for an individual patent-holder, the profits from the sale of a patent are taxed as capital gains while any damage awards from litigation are taxed as ordinary income. This means that capital gain tax rates affect the incentives to sell patents, but not the incentives to undertake patent litigation.

The main empirical findings in the paper are as follows. First, capital gains taxation significantly affects the decision to trade patent rights. This finding is consistent with previous literature studying the impact of capital gains taxation on the level and timing of the sale of small businesses (Chari, Golosov, and Tsyvinski, 2005; Gentry, 2010). Simulations using parameter estimates show that changes in capital gains taxation can have large effects on the extent of patent trading and litigation. Second, we find that changes in patent ownership reduce the probability of litigation for patents originally owned by individual inventors, at least on average. This implies that enforcement gains dominate commercialization gains in the market for innovation for such patents.

Third, however, we show that the marginal treatment effect of trading is heterogeneous, in ways that are consistent with the economics underlying the decision to trade and the two sources of gains from trade. First, the results suggest that the market for innovation reallocates patent rights efficiently. Specifically, patents that have larger estimated (enforcement) gains from trading are those with the highest estimated probability of changing ownership. Second, we show that these heterogeneous effects depend on the patent portfolio size of the buyer and on the technological fit of the traded patent in that portfolio. Sales by individual inventors to other individuals or small firms are not associated with reductions in the post-trade probability of litigation. In contrast, sales to firms with larger patent portfolios significantly reduce litigation risk. This is consistent with the economies of scale in enforcement first documented by Lanjouw and Schankerman (2004).[1] In addition, holding the portfolio size of the buyer constant, we find that reallocation of patents increases litigation risk more when the traded patent is a better technological fit in the buyer's existing portfolio. This is what we expect since the potential commercialisation gains from the transfer are likely to be larger in such cases.

Taken together, our empirical findings indicate that a well-functioning market for innovation is important for allocating patent rights efficiently, and that taxation affects this process. As long as small innovators can appropriate part of the commercialisation and enforcement gains generated by these transfers, this market increases their incentives to innovate.

The paper is organized as follows. In Section 2 we present a simple model that highlights the commercialisation and enforcement gains from trade, the impact of trade on litigation, and the role of taxation. Section 3 describes the data. In Section 4 we develop the baseline econometric model for estimating the local average treatment effect of trade on litigation, and present the results. In Section 5 we allow for heterogenous marginal treatment effects, and empirically link them to characteristics of the trade. Brief concluding remarks close the paper.

2 A Model of Patent Trade and Litigation

Consider an individual, A, owning a patent and a firm, B, willing to acquire the patent from the individual.[2] If the individual does not sell the patent, he obtains product market profits from commercializing (licensing) the innovation equal to π^A. If the patent is acquired by the firm, it generates product market profits equal to π^B. Both A and B face an infringing action by a third party, firm C with probability β. If the infringing action takes place, the patent owner chooses whether to litigate or settle the dispute. With litigation the patent owner $i = \{A, B\}$ sustains litigation costs l_i to secure product market profits. To settle the dispute, the owner gives up a fraction $(1 - \theta_i)$ of the profits to firm C. We also assume that there is a zero mean random (monetary) component in the settlement payoff, ε.

[1] Lanjouw and Schankerman (2001a, 2004) show that the litigation risk is systematically related to characteristics of the patent (including measures of value and the technology field) and of the patentholder. In particular, they find economies of scale in patent enforcement – firms with larger patent portfolios are more able to resolve disputes without resorting to the courts.

[2] In this paper we do not model the microfoundations of the search process through which matching occurs.

In this setup, there will be litigation if

$$\pi^i - l_i \geq \theta_i \pi^i + \varepsilon \tag{1}$$

which occurs with probability

$$\Pr\left\{\varepsilon \leq \pi^i(1-\theta_i) - l_i\right\}.$$

If the individual owner commercializes the patent, the profits are taxed at the personal income tax rate τ^I. If the patent is traded to the firm, the product market profits are taxed at the corporate income tax rate τ^C. If the individual owner sells the patent, the gains from the transaction are taxed at the capital gains tax rate τ^G. This setup conforms to the U.S. tax laws (see Section 4 for more details). For simplicity, we assume that the individual has all the bargaining power and extracts the entire surplus from the transaction (results are similar if there is Nash bargaining).

We refer to the vector $e^i = (l_i, \theta_i)$ as the "enforcement" vector of owner $i = \{A, B\}$. Litigation takes place with probability $\alpha\left(\pi^A; e^A\right) = \beta \Pr\left\{\varepsilon \leq \pi^A(1-\theta_A) - l_A)\right\}$ if the patent is owned by the individual and with probability $\alpha(\pi^B; e^B) = \beta \Pr\left\{\varepsilon \leq \pi^B(1-\theta_B) - l_B)\right\}$ if the patent is owned by the firm. Notice that $\partial\alpha\left(\pi^i; e^i\right)/\partial\pi^i > 0$ whereas $\partial\alpha\left(\pi^i; e^i\right)/\partial l_i < 0$ and $\partial\alpha\left(\pi^i; e^i\right)/\partial\theta_i < 0$.

To start, we consider the case in which there are no taxes. If the individual does not trade the patent, expected profits are:

$$\begin{aligned} & (1-\beta)\pi^A + \alpha\left(\pi^A; e^A\right)\left(\pi^A - l_A\right) + (\beta - \alpha\left(\pi^A; e^A\right))\theta_A \pi^A \\ = \; & (1-\Delta_A)\,\pi^A - \alpha\left(\pi^A; e^A\right) l_A \end{aligned}$$

where the term $\Delta_A = (\beta - \alpha\left(\pi^A; e^A\right))(1-\theta_A)$ captures the fraction of profits that are expected to be lost because of settlement between A and C and $\alpha\left(\pi^A; e^A\right) l_A$ captures the expected litigation costs. Similarly, if the patent is owned by firm B, profits are $\left[(1-\Delta_B)\,\pi^B - \alpha\left(\pi^B; e^B\right) l_B\right]$ where $\Delta_B = (\beta - \alpha\left(\pi^B; e^B\right))(1-\theta_B)$.

The individual will sell the patent if the following condition is satisfied:

$$\left[(1-\Delta_B)\,\pi^B - \alpha\left(\pi^B; e^B\right) l_B\right] \geq \left[(1-\Delta_A)\,\pi^A - \alpha\left(\pi^A; e^A\right) l_A\right]$$

This can be re-written as

$$\left(\pi^B - \pi^A\right) + \left(\Delta_A \pi^A - \Delta_B \pi^B\right) + \left(\alpha\left(\pi^A; e^A\right) l_A - \alpha\left(\pi^B; e^B\right) l_B\right) \geq 0. \tag{2}$$

Condition (2) highlights three possible sources of gains from trade. The first term captures "product market" gains, i.e. the greater profits that firm B obtains from selling the product. The second and third terms capture the "enforcement" gains which take the form of losing less profit from settlement, $\Delta_A \pi^A - \Delta_B \pi^B$, and incurring lower expected litigation costs, $\alpha\left(\pi^A; e^A\right) l_A - \alpha\left(\pi^B; e^B\right) l_B$.

It is straightforward to generalize the analysis in the presence of taxes. This yields the following conditions for the decision to litigate and to trade the patent:

$$(\pi^i - l_i)(1 - \tau^i) \geq \left(\theta_i \pi^i + \varepsilon\right)(1 - \tau^i) \tag{3}$$

$$\begin{gathered}\left[(1 - \Delta_B)\,\pi^B - \alpha\left(\pi^B; e^B\right) l_B\right]\left(1 - \tau^C\right)\left(1 - \tau^G\right) \geq \\ \left[(1 - \Delta_A)\,\pi^A - \alpha\left(\pi^A; e^A\right) l_A\right]\left(1 - \tau^I\right)\end{gathered} \tag{4}$$

where $\tau^i = \tau^I$ if $i = A$ and $\tau^i = \tau^C$ if $i = B$.

Note that the capital gains tax rate does not enter the first inequality that governs the litigation decision.[3] The second inequality, however, shows that the condition required to have trade becomes more stringent with an increase in τ^G (or a decrease in τ^I). A higher capital gains tax reduces the likelihood that patent rights are reallocated, and higher (personal) income tax rate increase it. We test these predictions in the empirical analysis, and exploit the capital gains tax rate as an instrument for trade based on it being excluded from the condition for litigation.

We now investigate how the level of litigation is affected by a change in patent ownership. Let T be an indicator variable equal to one if the patent changes ownership and zero otherwise. If individual A does not sell the patent, the probability of litigation is $\Pr(\mathit{Litigation}|T = 0) = \alpha\left(\pi^A; e^A\right)$. If trade takes place, the probability is $\Pr(\mathit{Litigation}|T = 1) = \alpha\left(\pi^B; e^B\right)$. Thus

[3] Note also that the probability of litigation α does not depend on the tax rate.

the impact of trade on litigation is

$$\Pr(Litigation|T=1) - \Pr(Litigation|T=0) = -\left[\left(\alpha\left(\pi^{A};e^{A}\right) - \alpha\left(\pi^{B};e^{B}\right)\right]. \qquad (5)$$

This equation shows that the effect of trade on litigation depends on whether it reallocates the patent to an entity with greater product market gains and/or lower enforcement costs. The effect of trade can be either positive or negative, depending on the difference $\alpha\left(\pi^{A};e^{A}\right) - \alpha\left(\pi^{B};e^{B}\right)$.

Previous literature has typically associated the surplus generated by patent trade with gains from vertical specialization (Teece, 1986) or comparative advantages in manufacturing or marketing (Arora and Ceccagnoli, 2006). In our model, this commercialisation hypothesis corresponds to the case where $\pi^{A} < \pi^{B}$ and $e^{A} = e^{B} = e$. Because $\partial\alpha\left(\pi^{i};e^{i}\right)/\partial\pi^{i} > 0$, in this case the change in patent ownership is unambiguously associated with an increase in patent litigation, since $\alpha\left(\pi^{B};e\right) - \alpha\left(\pi^{A};e\right) > 0$. Intuitively, in this scenario trade increases the product market profits generated by the patent but does not alter the enforcement capability of the owner. Because an increase in patent value increases the likelihood of patent litigation (Galasso and Schankerman, 2010), trade increases litigation rates if it is only motivated by product market gains.

By contrast, Lanjouw and Schankerman (2004) document that firms with large patent portfolios are less likely to file a suit on any individual patent in their portfolio (controlling for patent characteristics). This empirical finding corresponds to the case of a trade with a firm with large patent portfolio, such that the difference $\theta_B - \theta_A$ is positive and large enough to guarantee that $\alpha\left(\pi^{A};e^{A}\right) > \alpha\left(\pi^{B};e^{B}\right)$. In this case trade is associated with a reduction in the level of patent litigation.

3 Data

Our starting point is the panel of patents granted in the period 1975-2000 that are either (i) owned by the original inventor at the grant date or (ii) have been assigned to U.S. individuals before or at the grant date. Hall, Jaffe and Trajtenberg (2001) refer to the first group of patents as "Unassigned" and to the second group of patents as "U.S. Individuals" patents. The USPTO refers to both groups as "Individually Owned" patents. In total these patents represent 17.9

percent of the patents granted in the period 1975-2000. For each of these patents we obtained information on the U.S. state of the primary (first listed) inventor, their reassignment and litigation history. We also collected information on the U.S. state and federal ordinary income taxes and capital gain taxes for individuals during the sample period.

We now describe the main components of our data set.

Patent trade data: We follow Serrano (2010) and use re-assignment data to identify transfers of patents across firm boundaries. The source of these data is the USPTO Patent Assignment Database. When a U.S. patent is transferred, an assignment is recorded at the USPTO acknowledging the change in ownership. A typical re-assignment entry indicates the patent involved, the name of the buyer (i.e. assignee), the name of the seller (i.e. assignor), the date at which the re-assignment was recorded at the patent office and the date at which the private agreement between the parties was signed. The data set covers the period 1983-2001.

Under Section 261 of the U.S. Patent Act, recording the assignment protects the patent owner against previous unrecorded interests and subsequent assignments. If the patentee does not record the assignment, subsequent recorded assignments will take priority. For these reasons, patent owners have strong incentives to record assignments and patent attorneys strongly recommend this practice (Dykeman and Kopko, 2004).

A challenge in using re-assignment data is to distinguish changes in patents ownership from other events recorded in the USPTO assignment data. To this end, we use an algorithm developed in Serrano (2010) that conservatively drops all the assignments that appear not to be associated with an actual patent trade. Specifically, we drop assignments in which the buyer is the assignee at the grant date of the patent, and assignments recorded at the patent application date. We also dropped transfers to financial institutions to eliminate transactions (recorded in the USPTO Patent Assignment Database) in which a patent is used as collateral.[4] Another concern is that the first assignment of an unassigned patent may not correspond to a trade but rather to the transfer of ownership from the inventor to the company in which the inventor works. To deal with this concern, we drop any transactions where there is evidence that the

[4]We also dropped records in which the buyer and seller are the same entity and in which the execution date is either before the application date or after patent expiration. For additional details on the procedure, see Serrano (2010).

seller is an inventor working for the buyer.[5]

Litigation data: The patent litigation data set was compiled by Lanjouw and Schankerman (2001a, 2001b, 2004). This data set matches litigated patents identified from the Lit-Alert database with information on the progress or resolution of suits from the court database organized by the Federal Judicial Center. The data set contains 14,169 patent cases filed during the period 1975-2000. For each of these case filings, the data set reports detailed information on the main patent litigated, the patentee, the infringer and the court dealing with the case. The data set contains information on patent cases filed in U.S. federal district courts (and not on appeal). For each patent in our data, we identify the suits in which the patent was involved and the year in which the case was filed. In general, the use of re-assignment data as a proxy for the market for innovation can be problematic because technology can be transferred through patent licensing without changes in ownership. This concern is less relevant in our study that focuses on patent litigation because typically it is the owner of the patent that has the right to bring forth a patent infringement action, not the licensee.[6]

Tax data: Information on state and federal income and capital gain taxes are obtained from the NBER Tax Rates data base. This data set contains income tax rates by year and state for an additional $1,000 of income for a representative household (with $500,000 of wage income split evenly between husband and wife).[7] The data set also reports maximum federal and state long-term capital gains tax rate by year and state. These rates are computed using the NBER TAXIM model. Using these data, for each patent in our data set we obtain information on the ordinary income and capital gains marginal tax rates in the state of the patent assignee. For unassigned patents, we used the state of the primary inventor as identified by the USPTO.

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[5] Specifically, for each transfer between a seller i and buyer j ,we identified all the patents which list the seller i as the (primary) inventor and checked whether any of these patents was assigned to the buyer j at its grant date. We drop all such transactions.

[6] Non-exclusive licensees do not have the right to sue for patent infringement (Textile Prods. v. Mead Corp., 134 F.3d 1481, 1485 Fed. Cir. 1998.). Nonetheless, the Court of Appeal for the Federal Circuit has ruled that an exclusive licensee may have standing to sue for patent infringement (Prima Tek II, L.L.C. v. A-Roo Co., 222 F.3d 1372, 1377 Fed. Cir. 2000).

[7] The taxpayer is assumed to be married and filing jointly. A mortgage interest deduction of $50,000 and the calculated state income tax are present as personal deductions. The TAXSIM program is described in Feenberg and Coutts (1993). The simulation and the resulting data are available at http://www.nber.org/~taxsim/state-rates/

Matching data on income and capital gain taxes to patents is meaningful as long as the patent is owned by an individual at the time of the transaction. To ensure this, we focus our analysis on the first transfer of a patent. Subsequent owners are generally not individuals and thus are not subject to either personal income or capital gains taxation on the patent transaction. Focusing on the first transfer involves dropping very few patent trades. Most of the traded patents in our data are traded only once (94.9 percent) and only 0.15 percent of traded patents are traded more than three times.

The final data set is a panel with 299,356 patents and 2,436,649 patent-age observations. The main variables used in the empirical analysis are described below.

Litigated$_{it}$**:** dummy variable equal to 1 if at least one suit is filed in a federal court involving patent i at age t.

NewOwner$_{it}$**:** dummy variable equal to 1 for patent-ages in which the patent is no longer owned by the original individual assignee/inventor.

Income tax$_{it}$**:** for each patent-age, the sum of the federal income tax rate and the state income tax rate for the state of the primary (first listed) inventor of the patent.

Capital gains tax$_{it}$**:** for each patent-age, the sum of the federal capital gain tax rate and the state capital gain tax rate for the state of the primary (first listed) inventor of the patent.

Table 1 reports summary statistics for the key variables. Panel A shows the fraction of sample patents involved in trade or litigation at least once in their life. Of the total sample, 4.55 percent of patents are traded and 0.69 percent are involved in at least one suit. These rates are low but it is worth noting that, for the later patents in the sample, data on trade and litigation are truncated and this biases downward litigation and trade rates.[8] Moreover, patents that are traded or litigated are much more valuable than the those that are not (as measured by citations received).[9] The most striking fact from this table is the strong association between trading and litigation. Of patents that are traded, 4.2 percent are also litigated; for patents

[8] For patents where we have litigation and trade data during the first ten years of life (i.e. patents granted in 1983-1991), we find that 11.8 percent are traded and 2.2 percent are litigated.

[9] The mean number of citations for patents that are neither traded nor litigated is 6.1. The mean is 10.8 for traded patents and 16.5 for litigated patents. For those that are both traded and litigated, the average is 19.3.

that are not traded, the litigation rate is only 0.51 percent. Of patents that are litigated, 27.9 percent are also traded; for patents that are not litigated, only 4.4 percent are traded.

The second panel of Table 1 illustrates the combined (state plus federal) rates averaged across states for four five-year time periods. There is a substantial decline in income tax rates in the late eighties and an increase in the early nineties. Conversely, there is an increase in capital gain tax rates in the late eighties and a decrease in the late nineties. The summary statistics show the range of variation across U.S. states. The difference between the lowest and the highest capital gains tax rates across states ranges from 7-9 percentage points (depending on the year). The difference between the minimum and the maximum income tax rate across states is 6-16 percentage points.[10] Analysis of variance shows that 89.4 percent of the total variance in capital gains tax rates is variation over time and 8.7 percent is variation across states (the small remainder is residual). For ordinary income tax rates, the figures are 92.9 and 6.8 percent, respectively

Panel A in Table 1 shows that trade and litigation are associated, but it does not reveal how litigation rates differ before and after a trade occurs. To show this, we focus on patents that are eventually traded (in our sample period). In Figure 1 we compare the probability of being involved in at least one suit prior to and after the date at which trade occurs. In aggregate, a patent that has not been traded but that will be traded in its lifetime is involved in at least one suit in that year with probability 0.61 percent. A patent that has already changed ownership is involved in at least one suit with probability 0.48 percent. We observe that the post-trade litigation probability is lower even after we condition on age. For example, a patent that has not yet been traded at age 7 is involved in at least one dispute with probability 0.76 percent, whereas for a patent of the same age that has been already traded, the litigation rate is about that level (0.43 percent). In short, Figure 1 suggests that the reallocation of patent rights is temporally related to lower litigation risk. In the econometric analysis we try to pin down the causal relationship.

In principle, exploiting the information contained in the USPTO assignment data it is possible to recover the patenting activity of the buyers in our sample. Unfortunately, the

[10] Similar figures are observed if we restrict the analysis to the 20 states with the most individually-owned patents.

names of the buyer and seller in the Patent Assignment Database were never standardized by the USPTO. Therefore, to back out buyer patent portfolios we need to match each buyer name manually with a unique assignee identifier required to identify the buyer's patents. Because of the large size of our sample (17,605 traded patents), we manually matched only patents that were both traded and litigated at least once in their lifetime (569 patents). In the empirical analysis below, we will present the main regression results both for the entire data set (299,356 patents) and for the smaller data set of traded and litigated patents, where we are able to investigate the role of buyer characteristics on the impact of trade .

4 Estimating the Effect of Trade on Litigation

4.1 Baseline Econometric Model

Let L_{it} denote an indicator variable that is equal to 1 if at age t (year τ) at least one patent case is filed involving patent i. We assume that patents are litigated according to the following linear probability model:

$$L_{it} = \beta X_{ot} + \mu_i + \lambda_\tau + a_t + u_{it}$$

where X_{ot} are the characteristics of the owner at age t and u_{it} is the residual component. The terms μ_i, λ_τ and a_t capture patent fixed effects, year effects and age effects.[11]

Letting j denote the initial owner of the patent and k the buyer of the patent, we can write

$$X_{ot} = (1 - T_{it})X_j + T_{it}X_k$$

where T_{it} is a dummy that equals one from the date the patent changes ownership, and X_j and X_k are owners characteristics that we assume are constant over time for simplicity. Then the litigation model can be expressed as

$$L_{it} = \beta X_j + T_{it}\beta(X_k - X_j) + \mu_i + \lambda_\tau + a_t + u_{it}. \tag{6}$$

Equation (6) provides useful guidance in interpreting our empirical results. In the next

[11] The patent grant year is absorbed by the patent fixed effect. We are able to include age effects here, in addition to year effects, because we define the age of the patent relative to the specific date (not just the year) at which it was granted. Thus a patent granted on 2 May 1995 is one year old until and including 1 May 1996.

section we will regress litigation on trade in panel regressions of the form

$$L_{it} = \alpha T_{it} + \theta_i + \lambda_\tau + a_t + u_{it}. \tag{7}$$

In light of equation (6), the patent fixed effects, θ_i, will capture the combined effect of the characteristics of the initial owner, βX_j, and the patent characteristics, μ_i (i.e., $\theta_i = \beta X_j + \mu_i$). More importantly, the coefficient on the traded dummy, α, can be rewritten as $\beta(X_k - X_j)$. This has two implications. First, we can interpret the coefficient on trade as the impact that the change in ownership characteristics (if unobservable to the econometrician) has on patent litigation. If we were able to control for all the owner characteristics that affect litigation risk, the coefficient α should be zero. The second implication is that α will differ from zero only if two conditions hold: first, there are unobservable owner characteristics that affect litigation outcomes (i.e., $\beta \neq 0$). and, secondly, the market for innovation reallocates patents to entities that differ substantially in these characteristics (i.e., $X_k \neq X_j$). Previous literature on patent litigation confirms that owner characteristics substantially affect litigation risk (e.g., Lanjouw and Schankerman, 2004), but there is no existing research on the link between the reallocation of patent rights and litigation risk. To our knowledge, this is the first paper that studies this link and the sorting which the market for innovation induces.[12]

Identifying the Local Average Treatment Effect

To identify the causal effect of trade on litigation, we need to address the potential bias arising from correlation between T_{it} and u_{it}. This can arise in a variety of ways. A positive shock in the value of the technology covered by the patent may lead to an increase both in the likelihood of trade and litigation. Alternatively, a cash constrained innovator may be more likely to sell its patent and less likely to enforce it aggressively. Another possibility is that litigation may increase because firms acquire patents strategically with the purpose of blocking competitors

[12] It is easy to extend the model to introduce observable characteristics of the owner. Consider the model $L_{it} = \beta X_{ot} + \gamma \widetilde{X}_{ot} + \mu_i + \lambda_\tau + a_t + u_{it}$ where X_{ot} are the unobservable characteristics of the owner at age t and $\widetilde{X}_{ot}$ are the observable characteristics of the owner. Because $\widetilde{X}_{ot}$ are observed, we can estimate $L_{it} = \alpha T_{it} + \theta_i + \gamma \widetilde{X}_{ot} + \lambda_\tau + a_t + u_{it}$. In this extended model, the patent fixed effects, θ_i still captures the combined effect of the time invariant *unobservable* characteristics of the initial owner, βX_j, and the time invariant patent characteristics, μ_i (i.e., $\theta_i = \beta X_j + \mu_i$). The coefficient on the traded dummy, α, can be still be rewritten as $\beta(X_k - X_j)$ and measures the impact that the change in *unobservable* ownership characteristics has on patent litigation. This extension also implies that if the econometrician is able to observe all the patent characteristics that have an impact on litigation (i. e. X_{ot} is empty) then α would be equal to zero.

through patent litigation.

To address potential endogeneity, we need an instrument that affects the likelihood of trading a patent but does not belong directly in the litigation equation. We exploit a feature of the U.S. tax code that allows us to use the capital gain tax rates as an instrument. In the United States Internal Revenue Code, individuals face a lower tax rate on capital gains (from sales of assets) than on ordinary ('earned') income. U.S. corporations do not receive this preferential tax rate on capital gains (Desai and Gentry, 2004). According to section 1235 of the Internal Revenue Code, the transfer of a patent by an individual is treated as the sale of a capital asset and is subject to capital gain taxes. On the other hand, patent litigation damages (and licensing royalties) are taxed as ordinary income. This treatment of litigation damages is acknowledged in a number of tax court decisions (Maine and Nguyen, 2003). This means that the decision to trade a patent will be affected by the capital gains tax rate, but the decision to litigate will not. We limit the analysis in this paper to trades of individually-owned patents because this tax distinction does not apply to patent sales by corporations, so we cannot use this instrumental variable for transfers of company-owned patents.

We start by specifying a probit equation that determines how taxes affect the probability that a patent is traded by the original assignee at age t. To do this, we generate a dummy variable, $Trade_{it}$, that equals one only in the year in which the patent changes ownership. We drop all the observations that follow the first change in ownership and estimate the following probit regression:

$$Trade_{it} = \begin{cases} 0 & \text{if} \quad p(Z_{it}, X_{it}) \leq \varepsilon_{it} \\ 1 & \text{if} \quad p(Z_{it}, X_{it}) > \varepsilon_{it} \end{cases} \tag{8}$$

where Z_{it} is the capital gains tax rate for individuals in the state of the inventor and X_{it} is a vector of patent characteristics and additional controls. Given the probability of being traded at age t, p_{it}, we can compute the probability that the patent in not owned by the original assignee at age t as

$$P_{it} = P_{it-1} + (1 - P_{it-1})p_{it}$$

with $P_{i1} = p_{i1}$. Intuitively, the probability of not being owned by the original inventor at age t is equal to the probability of having changed ownership in the previous periods plus the probability of not having changed ownership up to age t and being traded at age t.

Denote the predicted probability from the probit model (8) as $\widehat{p}_{it}$. We use $\widehat{p}_{it}$ to obtain an estimate of the probability of not having changed ownership up to age t, $\widehat{P}_{it}$. This estimate satisfies two important properties. First, $\widehat{P}_{it}$ depends on capital gain tax rates Z_{it} that are assumed to be uncorrelated with the likelihood of patent litigation (except through changes in ownership). Second, $\widehat{P}_{it}$ is a monotonically decreasing function of Z_{it}. Specifically, we expect larger capital gain tax rates to reduce the probability of a change in ownership.[13] These properties allow us to exploit $\widehat{P}_{it}$ to estimate the local average treatment effect (LATE): the effect of a change of ownership for those patents whose owners were induced to sell their patents by a change in capital gain taxation. Specifically, identification of the LATE requires that the econometric setting satisfies two conditions: (i) conditional independence and (ii) monotonicity (Imbens and Angrist, 1994). Conditional independence captures the notion common to all instrumental variable procedures that any effect of Z on L must be via an effect of Z on T. Monotonicity requires that, while the instrument might have no effect on some patents, all of the patents that are affected should be affected in the same direction. The average treatment effect is "local" because not all patent owners are induced by the instrument to sell the patent.

Following Angrist, Imbens and Rubin (1996), we define $T(Z_{it})$ as a random variable equal to zero if patent i would not have changed ownership if it had the instrument equal to Z_{it}, and equal to one if that patent would be traded at Z_{it}. We observe (Z_{it}, T_{it}, L_{it}) for a random set of patents, where $T_{it} = T(Z_{it})$ is the trade indicator associated with Z_{it}, and $L_{it} = L(T_{it})$ is the response variable given the trade status T_{it}. Using this notation, the econometric model can be summarized by

$$\begin{aligned} L(T(Z_{it}) &= 1) = \alpha + \theta_i + \lambda_\tau + a_t + u_{it} \\ L(T(Z_{it}) &= 0) = \theta_i + \lambda_\tau + a_t + u_{it} \\ T(Z_{it}) &= \begin{cases} 0 & \text{if } \; P(Z_{it}) < v_{it} \; \text{ and } T_{it-1} = 0 \\ 1 & \quad \text{otherwise} \end{cases} \end{aligned} \tag{9}$$

[13] Because $\widehat{P}_{it}$ is a non-linear function of $\widehat{p}_{it}, \widehat{p}_{it-1}, ..., \widehat{p}_{i1}$, it depends on the entire vector of current and past capital gain taxation rates $\overline{Z}_{it} = (Z_{i1}, Z_{i2}, ..., Z_{it})$. Nonetheless, the relevant thing in our setting is that, conditional on a patent not having been traded, a change in ownership only depends on Z_{it}.

where α is the LATE identified using the instrument Z. [14],[15]

An important restriction implied by the LATE framework is that Z_{it} is independent of u_{it} and v_{it}. This assumption is consistent with the theoretical framework developed in Section 2 in which a patentee chooses whether to sell or not a patent i. In that model, when $T = 0$ the patent is owned by the individual and litigation rates are not affected by the capital gain taxes. When a change in ownership takes place ($T = 1$), the rate of litigation is also not affected by the level of capital gain taxes. Therefore, the probability of litigation is only affected by the instrument through the change of ownership switching from $T = 0$ to $T = 1$.[16]

4.2 Empirical Results

Trade and Litigation: Correlations

In Table 2, we begin by presenting OLS estimates of our baseline econometric model (7). The first three columns present estimates using the full sample (including patents that are not traded and/or litigated). In column 1, where we do not include any controls, the coefficient on the NewOwner dummy is positive and significant, suggesting that patents that change ownership are more likely to be involved in suits. However, this result is likely selection in trading, since more valuable patents are both more likely to be traded and litigated. In column 2 we include patent fixed effects in the specification to control for this possibility. This specification makes

[14] We assume that the disturbance in the litigation equation, u_{it}, does not depend on whether the patent is traded. It is easy to generalise to allow for different disturbances.

[15] Notice that, conditioning on a patent not having changed ownership ($T_{it-1} = 0$), trade occurs if $p(Z_{it}) > \varepsilon_{it}$. Multiplying both sides of the inequality by $(1 - P_{it-1})$ and adding P_{it-1}, we obtain

$$P_{it} > v_{it} \equiv P_{it-1} + (1 - P_{it-1})\varepsilon_{it}$$

This is the relationship between T and P described in the third formula of the econometric model. Even if the ε_{it} are assumed to be independent draws, the impact of v_{it} on T depends on the entire sequence of past realizations of ε_{it}. The serial correlation in v_{it} is not a problem as long as v_{it} is uncorrelated with Z_{it}.

[16] The LATE assumptions would also be satisfied in an alternative setting in which the seller needs to pay a search cost to be matched with the buyer. In that extended model, a reduction in capital gain taxes would induce the seller to pay the search cost and consider the opportunity to trade with the buyer. The LATE assumptions are satisfied because the instrument does not affect litigation in any other way than through the change of ownership. The LATE conditions may be violated, however, in a more complex model in which the seller has to search for the best match from a pool of potential buyers. In this model with multiple searches, the quality of the match between seller and buyer will depend on the intensity of the search of the seller. A lower capital gain tax may increase the search intensity of the seller and thus generate better matches. In this case, conditional on trading ($T = 1$), the quality of the match will vary with the capital gain tax rate.

use only of within-patent litigation variation.[17] Once fixed effects are included, the coefficient becomes negative and significant, indicating that a patent is *less likely* to be involved in a suit after it changes ownership. A Hausman test strongly rejects the null hypothesis that the patent effects are random.[18] The negative correlation between change of ownership and litigation is robust when we introduce age effects and time period dummies, in column 3.[19]

In columns 4-6 we present similar regressions using the much smaller subsample of patents that are both traded and litigated at least once in their life. In this case we find negative correlation between trading and litigation even when we do not include patent fixed effects. This is not surprising since in this subsample all patents are traded at some point in their life, so the selection into trading that explains the positive coefficient in column 1 does not play a role here. In this smaller sample the magnitude of the correlation drops substantially once we add fixed age and period dummies.

The results in Table 2 are to be interpreted as correlations between litigation rates and changes in ownership, not causal impacts. As we argued above, there are a number of reasons why we should expect unobservable factors to affect both the trading and litigation decisions. This intuition is confirmed by a Rivers-Vuong test that provides strong evidence against the exogeneity of patent trade.[20] To address this endogeneity we will now construct an instrument that relies on the effect of capital gains taxes on patent trading.

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[17] As an example of the within-patent variation used to identify the coefficient on trade, consider patent 4,424,900 covering anti-static packages and packaging material. The patent was granted in January 1984 to Robert J. Petcavich from San Diego, CA. In 1988 Petcavich files three infringement cases in the district of California against Richmond Technology Inc., Stoneman John Inc. and Noland Paper Co. In January 1991 the patent is sold to the to Minnesota Mining and Manufacturing Company that never litigates the patent.

[18] To perform the test, we run a random effect panel regression with additional covariates. The additional controls are the number of citations made by the patent, the number of citations received, the number of claims, and the technology class of the patent. The random effect coefficient on NewOwner is positive and significant in the random effect specification ($\hat{\beta} = 0.003$, $p - value < 0.01$). The estimate from the fixed effect specification is negative and significant ($\hat{\beta} = -0.002$, $p - value < 0.01$). We strongly rejects that the two estimates are equal ($\chi^2_{20} = 1878.19$, $p - value < 0.01$).

[19] In this regression we add dummies for four sub-periods: before 1986, 1986-90, 1991-95, and after 1995). In a more general specification with a dummy for each year, we do not reject the joint hypothesis that the individual year coefficients can be summarised by these four period dummies.

[20] Following Rivers and Vuong (1998), we regressed NewOwner on capital gain taxes, age dummies and period dummies in a linear probability model with fixed patent effects. We constructed the residuals ($\hat{v}$) for this model and then regressed the litigated dummy on NewOwner, age, period dummies and $\hat{v}$. The coefficient on $\hat{v}$ is positive and highly significant (point estimate of 0.054, $p - value < 0.01$).

Impact of Taxes on Patent Trading

Table 3 presents parameter estimates for the (causal) impact of capital gains and income tax rates on changes in patent ownership. The dependent variable is an indicator variable, $Trade$, that equals one only in the year in which the patent changes ownership. Because tax rates affect the initial owner incentives to sell the patent up to the time at which the patent is sold, we estimate these regressions dropping all observations that follow the first change in ownership. In all the regressions we control for a range of observable patent characteristics, including the number of citations received by the patent, a measure of the patent generality, technology class (36 two-digit sub-categories), plus year and age fixed effects.[21]

Column 1 presents the estimates of the probit model (8). In line with the results in Serrano (2010), we find that more valuable and general patents are more likely to be traded. The important, new results involve the impact of taxes. The regression confirm that higher capital gains tax rates reduce the likelihood that patent rights are traded, and higher income tax rates increase it. These results are consistent with the predictions of the model presented in Section 2. Moreover, the magnitude of the tax impact is quite large. The marginal effects in column 1 imply that an increase in the capital gain tax rate of one percentage point reduces the probability of being traded by about 0.02 percentage points. An increase in income tax rates of one percentage point increases the likelihood of trade by 0.01 percentage points. In column 2 we show that results are similar if we use a linear probability model.[22]

In columns 3 and 4 we focus on the sub-sample of patents that are litigated and traded at least once in their lifetime. Despite the huge reduction in sample size, we still find a negative and significant coefficient for capital gains tax rates. In this restricted sample the estimated coefficients on citations received and generality are not significant. This is not surprising

[21] We use the NBER data set for information on the number of citations received, grant date and technology class for each patent. Since citation counts are inherently truncated, we use the truncation adjusted citations counts contained in the NBER patent data (see Hall et. al., 2001, for details). The NBER data also provides an index of patent "generality". This measure equals to one minus the Herfindahl index of the citations received by a patent across different technology classes. The measure is high if the patent is cited by a wide range of technology fields.

[22] The results are robust to introducing patent fixed effects in the linear probability model, where we obtain a coefficient of -0.118 ($p-value = 0.01$) and a 95 percent confidence interval that includes the point estimate in column 2. The marginal effect for capital gain taxes is also similar if we estimate using a logit specification, even with a correction for rare events (King and Zeng, 2001).

because all the patents in this smaller sample are traded, and our time-invariant measures of patent characteristics have little explanatory power on the *timing* of trade.

This evidence strongly supports the hypothesis that capital gains (and personal) income tax rates affect the likelihood that patent rights are traded. Since market based reallocations presumably increase the surplus generated by the patented innovations, the fact that taxes play a role in this process is of independent interest, quite apart from the usefulness of capital gains taxes as an instrument for identifying the impact of such trade on litigation. Our finding is also consistent with recent studies that document the impact of capital gains taxation on the frequency and timing of small business transfers (Chari, Golosov and Tsyvinski, 2005; Gentry, 2010).

Causal Effect of Trade on Litigation

The parameter estimates from the regressions in Table 3 allow us to compute the probability that a patent is traded *at a specific age*, $\widehat{p}_{it}$. Define the indicator variable $NewOwner_{it} = 1$ if ownership of the patent has been transferred from the original assignee *by age t,* and zero otherwise.[23] The estimate of $\widehat{p}_{it}$ can be used to construct an estimate of the probability that $NewOwner_{it} = 1$,which we denote by $\widehat{P}_{it}$. To estimate the LATE, we use this constructed variable, $\widehat{P}_{it}$, as an instrument for the endogenous variable, $NewOwner_{it}$. Econometrically, the exogenous variation is derived from the capital gain tax rates, but any monotonic function of this variable can be used as an instrument and $\widehat{P}_{it}$ is a typical choice when the endogenous variable is binary (see discussions in Imbens and Angrist, 1994 and Llieva and Trefler, 2010). In all the first-stage regressions, $\widehat{P}_{it}$ is strongly correlated with the indicator variable $NewOwner$, and the F-tests of joint exclusion of the instruments do not indicate problems of weak instruments.[24]

Table 4 presents the parameter estimates using this IV strategy. Column 1 reports estimates when $NewOwner$ is instrumented by the $\widehat{P}_{it}$ constructed from the probit regression in column 1 of Table 3. Column 2 shows that the estimated coefficient is nearly identical if the instrument is obtained from the linear probability model. In both regressions the estimated

[23] This indicator is equivalent to the variable T_{it} of the econometrics model.

[24] In all the tests the p-value <0.01.

causal effect of a change in ownership on litigation is negative and significant, and the point estimate (in absolute value) is about six times larger than the simple OLS estimate in column 3 of Table 2. This result highlights the importance of controlling for the endogeneity of trade, and indicates a positive correlation between NewOwner and the disturbance in the litigation equation (inducing a downward bias if we treat changes in ownership as exogenous).

In columns 3 and 4 we present similar IV regressions using the sub-sample of traded and litigated patents. In this case too the estimated coefficient on the change in ownership variable is negative and significant, and much larger in absolute value than the OLS estimates in Table 2.

For the full sample, the estimate of the LATE indicates that a change in ownership reduces the annual litigation probability by about 1.1 percentage points. In the sub-sample of traded and litigated patents, the causal effect is an order of magnitude larger, corresponding to a reduction in litigation probability by about 15 percentage points. While the difference in the magnitude of the marginal effect across the two samples is very large, the implied semi-elasticities (percentage change in litigation probability) are fairly similar (i.e., the differences in marginal effects are driven by differences in the mean litigation probability). Evaluated at sample means, the implied semi-elasticity is -0.43 (std.dev.=0.10) in the full sample, and -0.79 (std.dev.=0.37) in the restricted sample.

The estimated LATE measures the effect of trade on the unidentifiable sub-population of patents that change ownership because of a change in capital gains taxation. Thus it is difficult to map the coefficients estimated in Table 4 to reductions in litigation rates for the average patent in our sample. A plausible assumption is to consider those sample patents that are litigated but not traded as "at risk" of being affected by a change in taxation. For these patents, the estimated LATE from column 4 implies a reduction in the annual litigation rate of about 11 percent.[25]

[25] Specifically, the average annual probabiliy of litigation among patents that are litigated (but not traded) at some point in their life is 0.103. Thus the percentage change implied by the estimate LATE is equal to -0.012/0.103=-0.116.

5 Heterogeneous Effects of Trade on Litigation

Estimation and Results

The econometric model developed in the previous section assumes that the effect of trade on litigation is identical across all the patents. We now consider heterogeneous effects and extend the model as follows:

$$\begin{aligned}
L_{it}(T_{it}(Z_{it}) &= 1) = \alpha_i + \theta_i + \lambda_\tau + a_t + u_{it} \\
L_{it}(T_{it}(Z_{it}) &= 0) = \theta_i + \lambda_\tau + a_t + u_{it} \\
T(Z_{it}) &= \begin{cases} 0 & \text{if } \; P(Z_{it}) < v_{it} \; \text{ and } T_{it-1} = 0 \\ 1 & \text{otherwise} \end{cases}
\end{aligned} \tag{10}$$

where θ_i are patent fixed effects, a_t and λ_τ are patent age and year effects. We assume that α_i can be decomposed into a common component ($\overline{\alpha}$) and a random component (ψ_i): $\alpha_i = \overline{\alpha} + \psi_i$. The heterogeneous effect of new ownership on litigation is

$$L_{it}(T_{it} = 1) - L_{it}(T_{it} = 0) = \overline{\alpha} + \psi_i.$$

Consider an increase in the value of the technology that makes the patent both more likely to be traded (small v_{it}) and more likely to be litigated after trade (high ψ_i). Together these imply that we should observe a negative correlation between ψ_i and v_{it}, and thus a negative correlation between v_i and the effect of trade on litigation. More formally we should expect $E(\overline{\alpha} + \psi_i | v_{it})$ to be decreasing in v_{it}. Because v_{it} is not observed it is not possible to condition on it. Nonetheless, for an inventor that is just indifferent between trading and not trading, it must be that $P(Z_{it}) = v_{it}$. Exploiting this equality, we obtain the marginal treatment effect $E(\overline{\alpha} + \psi_i | P(Z_{it}))$, which corresponds to the (heterogenous) effect of trade on litigation for patents that are traded because of the instrument.[26]

Heckman and Vytlacil (1999) show that

$$E(\overline{\alpha} + \psi_i | P = v_{it}) = \left. \frac{\partial E(L_{it}|P)}{\partial P} \right|_{P = v_{it}} \tag{11}$$

and establish identification of the marginal treatment effect. Specifically, for any patent, if $T_{it} = 1$ we observe $L_{it}(T_{it} = 1)$ and if $T_{it} = 0$ we observe $L_{it}(T_{it} = 0)$. Thus the observed

[26] For a formal treatment, see Heckman and Vytlacil (1999).

litigation is

$$\begin{aligned} L_{it} &= L_{it}(T_{it}=1)T_{it} + L_{it}(T_{it}=0)(1-T_{it}) \\ &= (\overline{\alpha}+\psi_i)T_{it} + \theta_i + \lambda_t + a_{it} + u_{it}. \end{aligned}$$

The marginal treatment effect (MTE) can be computed by estimating the expected litigation conditional on P, $E(L_{it}|P)$. Let $\widehat{P}$ be our estimate of the probability that a patent is not owned by the initial inventor. Plugging this into the observed litigation equation, we obtain a partially linear model

$$E[L_{it}|\widehat{P}_{it}] = E[(\overline{\alpha}+\psi_i)T_{it}|\widehat{P_{it}}] + \theta_i + \lambda_t + a_{it}. \tag{12}$$

The derivative of (12) can be semi-parametrically and non-parametrically estimated in order to obtain the marginal treatment effect. For the semi-parametric estimation, we follow Carneiro, Heckman, and Vytlacil (2003) and approximate $E[(\overline{\delta}+\psi_i)T|\widehat{P}_{it}]$ with a third order degree polynomial, obtaining

$$E[L_{it}|\widehat{P}_{it}] = c_1\widehat{P}_{it} + c_2(\widehat{P}_{it})^2 + c_3(\widehat{P}_{it})^3 + \theta_i + \lambda_t + a_{it}$$

which implies a MTE equal to $c_1 + 2\widehat{P}_{it}c_2 + 3c_3(\widehat{P}_{it})^2$.[27] For the non-parametric approach, we follow the multistep procedure developed by Heckman, Ichimura, Smith and Todd (1998) and Carneiro, Heckman, and Vytlacil (2003) (see appendix for details).[28]

Figure 2 shows the semi-parametric estimation of the MTE for the entire sample.[29] The horizontal axis depicts the estimated probability that the patent is not owned by the original inventor, $\widehat{P}$. The vertical axis shows the effect of trade on litigation for different values of $\widehat{P}$. The dashed lines are 95 percent bootstrapped confidence intervals. The support for $\widehat{P}$ goes up to 0.15, which corresponds to the 99th percentile for the measure. The absolute value of

[27] A simple test of heterogeneity suggested by Carneiro et. al. (2003) involves testing the null hypothesis that the coefficients of the second and third order are jointly equal to zero. The F-statistic for $\widehat{c}_2 = \widehat{c}_3 = 0$ is 24.28 ($p < 0.01$) in the sample for litigated and traded patents and 13.61 ($p < 0.01$) in the full sample.

[28] Specifically, the first part of the procedure involves estimating the litigation equation non-parametrically. This is a non-parametric counterpart of the IV estimates and it involves the use of local linear regressions. The second part of the procedure involves numerically differentiating the estimated $E[L|\widehat{P}_{it}]$.

[29] For the large sample, only the semi-parametric MTE could be estimated because running local linear regressions in a panel with more than 2 million observations is infeasible with the available computer hardware.

the estimated marginal treatment effect is monotonically increasing in $\widehat{P}$ and is statistically different from zero for most of the range of $\widehat{P}$, apart from the lowest values. Patents with low value of $\widehat{P}$ are patents that, given their observables, are unlikely to have changed ownership (e.g. patents that are not highly cited or with low generality index). The small (or insignificant) values of the MTE in this range indicate that if a change in capital gain taxes induced the owner of one of these patents to sell, the change in litigation risk would be negligible. Conversely, patents with high $\widehat{P}$ are patents that have high probability of being traded. For these patents the MTE is negative and statistically significant, indicating a substantial drop in the likelihood of litigation from transfer of ownership.

Figure 3 reports the non-parametric estimates of the MTE for the sub-sample of patents that are traded and litigated. The support for $\widehat{P}$ differs from the one in the previous figure because the estimated probability of a change in ownership is greater in the sample where all patents are traded. Also in this case we find that the absolute value of the estimated effect is monotonically increasing in $\widehat{P}$ and statistically significant for values of $\widehat{P}$ greater than 0.5. The figure looks similar if we estimate the MTE with the semi-parametric procedure employed for the larger sample.

These results are interesting for two reasons. First, they indicate that the main impact of trading in patent rights, over most of the range of $\widehat{P}$, is to reduce litigation risk, suggesting that comparative advantage in patent enforcement may be more important than comparative advantage in commercialisation, at least for transfers involving individually-owned patents. Second, the results suggest that the market for innovation reallocates patent rights efficiently. In particular, patents that have larger estimated (enforcement) gains from trading are those with the highest estimated probability of changing ownership.

Unbundling the Marginal Treatment Effect

The previous section confirms that the effect of trade on litigation is heterogenous, and that the effect reduces litigation more strongly for patents at greater risk of being traded. This suggests that the nature of the transactions varies and that there is a particular type of sorting: patents less likely to be traded (low values of $\widehat{P}$) being more likely in transactions based on commercialisation advantages, and patents with high values of $\widehat{P}$ more likely to be in transactions driven by enforcement gains. To understand this sorting better, in this section we unbundle the marginal treatment effect and relate it to observable characteristics of the transaction.

To perform this exercise, we need information on patent buyers. The USPTO reassignment data contain non-standardized names of the buyers, so buyers' characteristics must be manually recovered. We perform this manual match for the 569 patents that were both traded and litigated at least once in their lifetime. For each of these patents, we constructed the size of the portfolio of the buyer, defined as the number of patents obtained in the twenty years before the trade event. Our matching shows that most transactions involve trade from an individual owner to a firm. Only 11.4 percent of the cases involve two individuals. The distribution of buyer portfolio size is extremely skewed (mean = 106.1, std. dev. = 869.2). The median portfolio size for acquiring firms is one patent, and 75th percentile is only three patents.

We use the buyer portfolio to construct two variables to capture the two basic motivations for transactions: enforcement gains and commercialisation (product market) gains.[30] The first variable, $LargeBuyer$, is equal to one if the buyer's portfolio includes at least eight patents at the time of the transaction (i.e., if the buyer had that number of patents granted in the preceding twenty years). In our sample there are 24 transactions (about five percent) involving large buyers. Lanjouw and Schankerman (2004) show that firms with large patent portfolios are less likely to file a suit on any individual patent in their portfolios, controlling for patent characteristics, and argue that this reflects their abiity to resolve disputes 'cooperatively' without resorting to the courts. Building on this idea, we expect "enforcement gains" (reduction in litigation) to be greater for patents acquired by large buyers.

The second variable is designed to capture transactions where the traded patent is a good match for the technology profile of the buyer, where comparative advantage in manufacturing or marketing are more likely to be realized. We define $TechFit$ as a dummy variable equal to one if the acquired patent belongs to the technology area to which the plurality of the buyer's

[30] We also examine the possibility that changes in ownership may simply be the way patent disputes are settled rather than reflecting an efficient reallocation to entities that are less likely to resort to courts. To do this we compare the names of the parties trading a patent with those involved in litigation. There is very little overlap: in only 20 patent cases (3.5 percent of the sample of litigated and traded patents) does a patent transfer follow a suit filed by the same parties. This indicates that the main effect of trade is through comparative advantages in enforcement, and not through facilitating settlement of an existing dispute.

patents are assigned. To do this we use the 36 technology sub-categories defined in Hall et. al. (2001). The *TechFit* measure is equal to one for 140 patents (about 25 percent) of the sample. The hypothesis is that in such cases the product market gains from the transaction will be larger, and thus that such transactions tend to raise, not lower, litigation risk.

Table 5 presents instrumental variable regressions that examine how buyer portfolio size and patent fit affect the impact of trade on litigation. Column 1 confirms that patents traded to small entities that fit well in the portfolio experience an *increase* in litigation after they are traded. These are transactions where product market gains are expected to be important and enforcement gains are negligible. In sharp contrast, column 3 shows that the largest reduction in litigation rates occurs when patents are traded to large entities with low fit in the buyer patent portfolio, where enforcement gains are large and product market gains are small. Columns 2 and 4 show that trade is associated with a reduction in litigation of smaller magnitude for transactions where both sources of gains (or none of them) are present. In column 5 we confirm the results using the pooled sample and interacting the traded indicator with the dummies for large portfolio and patent fit. The point estimates in this regression imply that patents traded to small entities with high fit experience a 22 percentage point increase in their litigation rate, whereas for patents traded to large buyers with low fit there is a reduction of 57 percentage points.[31]

Table 6 shows that these results are robust to a number of alternative specifications. In column 1 we increase the large buyer threshold from 8 to 12 patents. Columns 2-4 use alternative constructions of the $TechFit$ measure. In the baseline regression we set $TechFit = 1$ when the buyer is an individual (in such cases we cannot measure the portfolio size). Column 2 uses the alternative $TechFit = 0$ in such cases. In column 3 we employ a $TechFit$ measure constructed using a finer technology classification (we move from 36 technology sub-categories to about 400 USPTO patent classes). Finally, in column 4 we use a citations-based $TechFit$ measure. Specifically, we define $TechFit = 1$ if either the acquired patent cites one of the

[31]The regression in column 5 is a constrained version of those in columns 1-4, where period dummies are the same across the different samples. In a more general specification we do not reject the hypothesis that the period dummies are the same across the four groups of transactions. In column 5 we allow the age dummies to differ across the samples because the data strongly indicated differences in the impact of these dummies in the first stage regression.

patents of the buyer or if the patents of the buyer cite the acquired patent.

In all these regressions the interaction between the $NewOwner$ indicator and $TechFit$ is positive and significant, and the interaction with the $LargeBuyer$ dummy is negative and significant. These results are consistent with the theoretical framework developed in Section 2, where the relative magnitude of “product market” and “enforcement” gains determine whether a change in ownership has a positive or negative impact on litigation.

These results also help explain the pattern of the marginal treatment effect, documented in Figures 2 and 3. The results suggest that patents with low values of $\widehat{P}$ are more likely to be involved in transactions driven by commercialization gains, and patents with high $\widehat{P}$ more likely to be involved in transactions driven by enforcement gains. To explore this idea further, we examine which the transactions at each level of $\widehat{P}$. Controlling for patent age, our data show that as $\widehat{P}$ increases there is a decline in the number of trades to small buyers with high $TechFit$ and a corresponding increase in the low $TechFit$ trades. For example, for patent age 5, about 30 percent of patents in the first quartile of the $\widehat{P}$ distribution are involved in high fit/small buyer transactions. The fraction drops to 16 percent for patents in the fourth quartile of the $\widehat{P}$ distribution. Among those patents, the fraction of low fit trade is about 65 percent in the first quartile, but 82 percent in the fourth quartile of the $\widehat{P}$ distribution.

6 Simulating Tax Effects on Trading and Litigation

The analysis of the previous sections used variation in capital gain taxes as an instrumental variable to estimate the causal effect of a change in ownership on patent litigation rates. In this section we use the parameter estimates to study the impact of capital gain taxes on the frequency of patent trade and patent litigation.

Let τ^G denote the capital gain tax rate, which we assume is constant for the entire life of a patent. Let $P_t(\tau^G)$ denote the probability that the patent has been traded by age t, L_{0t} be the likelihood of being involved in at least one dispute at age t if the patent is owned by the initial inventor, and L_{1t} be the likelihood of being involved in at least one dispute at age t if ownership has changed. Then the expected number of years in which at least one dispute is filed is

$$\begin{aligned}
E(L(\tau)) &= \sum_{t=1}^{T}(1-P_t(\tau^G))L_{0t}+\sum_{t=1}^{T}P_t(\tau^G)L_{1t} \\
&= \sum_{t=1}^{T}L_{0t}+\sum_{t=1}^{T}P_t(\tau^G)(L_{0t}-L_{1t}).
\end{aligned}$$

The estimates in Tables 3 and 4 can be used to computed $E(L(\tau^G))$ for the average patent in our sample. We measure L_{0t} as the predicted litigation probability for a patent of age t that has not changed ownership, using column 1 from Table 4. $L_{0t}-L_{1t}$ is computed with the local average treatment effect in column 1 from Table 4. $P_t(\tau^G)$ is the predicted hazard for different levels of capital gain taxes τ^G and can be constructed using the estimates in column 1 from Table 3.

We construct this estimate of $E(L(\tau^G))$ for different tax scenarios in order the study how taxes may affect the level of litigation. In the baseline scenario we assume $\tau^G = 29.2$ (percent), which is the average value in our sample and similar to the combined (State plus Federal) tax rate faced by an individual in Texas in 1995. In the second, low tax scenario we set $\tau^G = 20$, which is the lowest rate in our sample and is the combined rate faced in Florida in 1985. In the third, high tax scenario $\tau^G = 40$, which is close to the highest rate in our sample that was charged in California in 1997. In the last two scenarios we study the impact of removing the differential tax treatment of capital gains. First we increase the capital gains rate to be equal to the (personal) income tax rate. Second, we equate the two rates at the lower, capital gains rate.

Table 7 summarizes the results. In the baseline scenario the level of $E(L(\tau))$ is 0.013. Multiplying this number by the average number of disputes filed in each year in which the patent is litigated (1.2 in our sample) and adjusting for litigation under-reporting using the weights in Lanjouw and Schankerman (2001), we can translate $E(L(\tau))$ into a number of predicted disputes. Our computations predicts about 36 disputes every 1,000 patents. This estimate is very similar to the litigation level estimated in Lanjouw and Schankerman (2001), which for individuals is 35 disputes per 1,000 patents.

In the low tax scenario (a reduction in the capital gains rate by 9 percentage points), the number of traded patents nearly doubles and this generates a 38 percent reduction in the number of disputes (no about 22 per 1,000 patents). In the high tax scenario (an increase in the capital gains rate by 11 percentage points), there is a 47 percent reduction in the number of traded patents that is associated with a 27 percent increase in the number of disputes. Equalizing capital gains and income tax rates is associated with a contraction in the frequency of trade and an increase in litigation. The magnitude of the effect depends on whether the equality is reached by an increase in capital gains rate or a reduction in the income tax rate. The increase in litigation rates is stronger when capital gains rates are increased to the average level of income rates in our sample (42.6 percent).

7 Conclusions

In this paper we study the impact of the market for innovation on patent enforcement. Conventional wisdom associates the reallocation of patent rights through trade with comparative advantages in the commercialisation of the innovation. This view implies that the gains from trade should increase the likelihood of litigation of traded patents. We identify a new source of gains from trade, comparative advantage in patent enforcement, and show that this mechanism reduces patent litigation. Using data on trade and litigation of individually-owned patents in the U.S., and exploiting variation in capital gains tax rates across states and over time as an instrumental variable, we identify the causal effect of changes in patent ownership on litigation rates.

There are three key empirical findings in the paper. *First*, capital gains taxes have a substantial effect on the market transactions in patent rights granted to individual inventors. *Second*, the reallocation of these patent rights reduces the likelihood of litigation. This result indicates that for individually-owned patents, on average, enforcement gains dominate commercialization gains in the market for innovation. *Third*, the marginal treatment effect of trade on litigation is heterogeneous. Patents with larger potential gains from trading are those with the highest estimated probability of changing ownership. This result suggests that the market for innovation reallocates patent rights efficiently, at least in this sense. Moreover, the impact of trade is related to characteristics of the transaction – specifically, the size of the buyer's patent portfolio and the quality of the match, measured by the technological fit of the patent in that portfolio. Sales by individual inventors to other individuals or small firms are not associated with reductions in the post-trade probability of litigation, while sales to firms with larger patent portfolios significantly reduce litigation risk. This confirms the importance of economies of scale in enforcement, documented by Lanjouw and Schankerman (2004). For given portfolio size, we find that trade increases litigation risk more when the traded patent is a better technological fit in the buyer's existing portfolio, where we expect greater potential for commercialisation gains from the transfer.

The findings in this paper indicate that a well-functioning market for innovation is important for allocating patent rights efficiently *ex post*, and that taxation affects this process. As long as small innovators can appropriate part of the gains from patent trading, this market also increases their *ex ante* incentives to innovate.

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Appendix: Details on Non-Parametric Estimation

This section describes the details of the non-parametric estimation of the marginal treatment effect. Our approach is based on a multistep, non-parametric procedure of Heckman, Ichimura, Smith and Todd (1998) and Carneiro, Heckman, and Vytlacil (2003). We extend their procedure to a panel data setting to account for individual/patent fixed effects.

The first part of the procedure involves estimating the litigation equation non-parametrically. This is a non-parametric counterpart of the IV estimates found in Table 4.

1. STEP 1. Regress each of the variables in the vector X on $\widehat{P}$ using local linear regression. In our setting this involves running multiple regressions. In particular, we run a regression for each age dummy on $\widehat{P}$, a regression for each calendar dummy on $\widehat{P}$, and finally another regression of income tax rates on $\widehat{P}$. The regressions were run in STATA 10 using the command lpoly.

2. STEP 2. Let $\widehat{\varepsilon}_X$ be the residuals and vector of residuals from the regression in step 1. Regress L on $\widehat{\varepsilon}_X$ using OLS with patent fixed effects in order to obtain an estimate of the vector β_0.

3. STEP 3. Let $\widehat{\varepsilon}$ be an estimate of the residual from the previous OLS regression (accounting for the patent fixed effects). This is an estimate of $\beta_1 \widehat{P} + E[(\overline{\alpha} + \psi_i)T|\widehat{P}]$. Regressing $\widehat{\varepsilon}$ on $\widehat{P}$ using local linear regression allow us to obtain a non-parametric estimate of $\widehat{\varepsilon}(\widehat{P})$.

Putting all this together, we construct an estimate of $E[L|\widehat{P}]$, $\widehat{E[L|\widehat{P}]} = \widehat{\beta_0} X + \widehat{\mu}_i + \widehat{\varepsilon}(\widehat{P})$.

The second part of the procedure involves numerically differentiating $\widehat{E[L|\widehat{P}]}$. To do so, we divide observations into groups, based either on the deciles of the distribution of $\widehat{P}$ or the absolute value of $\widehat{P}$. Recall that the variable component of $\widehat{E[L|\widehat{P}]}$ with respect to $\widehat{P}$ is $\widehat{\varepsilon}(\widehat{P})$. The mean of $\widehat{\varepsilon}(\widehat{P})$ was calculated for each of these groups. The derivative of $\widehat{\varepsilon}(\widehat{P})$ were obtained by finite differencing across neighboring groups. The confident intervals of the marginal treatment effects were obtained with 50 bootstrap iterations (we used the seed = 123 in STATA 10).

TABLE 1. Summary Statistics

Panel A. Patent Trade and Litigation

		Patents Not Traded		Patents Traded		Total	
		N	col. perc.	N	col. perc.	N	col. perc.
Patents Not Litigated	N	284,281	99.49	13,038	95.82	297,319	99.31
	row perc.	95.61		4.39			
Patents Litigated	N	1,468	0.51	569	4.18	2,037	0.69
	row perc.	72.07		27.93			
Total	N	285,749		13,607		299,356	
	row perc.	95.45		4.55			

Panel B. Capital Gains and Income Tax Rates

	Capital Gains Tax Rates				Income Tax Rates			
Period	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
1982-1986	21.4	1.2	20	27	52.7	1.9	50	56.7
1987-1991	31.6	2.1	28	37	34.4	4.5	28	44.6
1992-1996	32.4	1.9	28.9	37	42.4	3.9	31.9	48.1
1997-2001	26.9	5.6	21.2	40.3	43.9	1.8	40.3	46.9

NOTES: Capital Gain Tax Rate: sum of federal and state capital gain tax rates in state of first inventor. Income Tax Rate: sum of federal and state income tax rates in state of first inventor.

TABLE 2: Trade and Litigation- Correlations

	1	2	3	4	5	6
Estimation Method	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**
Dependent Variable	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**
NewOwner x 10	0.039***	-0.025***	-0.019***	-0.261***	-0.514***	-0.056
	(0.003)	(0.004)	(0.004)	(0.082)	(0.100)	(0.153)
Age Dummies	NO	NO	YES	NO	NO	YES
Time Period Dummies	NO	NO	YES	NO	NO	YES
Patent Fixed Effects	NO	YES	YES	NO	YES	YES
Sample	Entire Sample	Entire Sample	Entire Sample	Litigated and Traded Patents	Litigated and Traded Patents	Litigated and Traded Patents
Patents	299,356	299,356	299,356	569	569	569
Observations	2,436,649	2,436,649	2,436,649	6,810	6,810	6,810

NOTES: Standard errors clustered at patent level are reported in parentheses. Statistical significance: *10%, **5%, *** 1%. Litigation Dummy = 1 if the patent is involved in at least one case at that age; NewOwner = 1 when the patent changes ownership for the first time and remains equal to one for the remaining life of the patent. Time Period Dummies: before 1985, 1985-1990, 1991-1994, after 1995.

TABLE 3: Impact of Taxes on Patent Trading

	1	2	3	4
Estimation Method	**Probit**	**OLS**	**Probit**	**OLS**
Dependent Variable	**Trade**	**Trade**	**Trade**	**Trade**
	Mar. Eff. x 10^3	**Coefficients x 10^3**	**Mar. Eff. x 10^2**	**Coefficients x 10^2**
Capital Gain Tax Rate	-0.213***	-0.328***	-0.501**	-0.610**
	(0.05)	(0.08)	(0.19)	(0.24)
Income Tax Rate	0.132**	0.197***	-0.021	-0.032
	(0.05)	(0.07)	(0.11)	(0.11)
Citations Received	0.061 ***	0.188***	0.015	0.015
	(0.00)	(0.00)	(0.03)	(0.03)
Generality	0.191*	0.049	5.572	5.375
	(0.10)	(0.15)	(2.65)	(2.61)
Age Dummies	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES
Technology Dummies	YES	YES	YES	YES
Patent Fixed Effects	NO	NO	NO	NO
Sample	Entire Sample until Traded	Entire Sample until Traded	Litigated and Traded Patents until Traded	Litigated and Traded Patents until Traded
Patents	259743	259743	558	558
Observations	2112507	2112507	3025	3025

NOTES: Standard errors clustered at patent level are reported in parentheses. Statistical significance: *10%, **5%, *** 1%. Trade= 1 when the patent changes ownership for the first time. Capital Gain Tax Rate: sum of federal and state capital gain tax rates in state of first inventor. Income Tax Rate: sum of federal and state income tax rates in state of first inventor. Citations Received: truncation-adjusted forward cites. Generality: see Hall et al. (2001). Technology Dummies are generated using the 36 technology sub-categories defined in Hall et al. (2001).

TABLE 4: Impact of Trade on Litigation - Instrumental Variable Estimation

	1	2	3	4
Estimation Method	**2SLS**	**2SLS**	**2SLS**	**2SLS**
Dependent Variable	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**
NewOwner (Instrumented)	-0.012**	-0.011**	-0.181**	-0.137**
	(0.005)	(0.004)	(0.075)	(0.071)
Income Tax Rate	-0.001	-0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Age Dummies	YES	YES	YES	YES
Time Period Dummies	YES	YES	YES	YES
Patent Fixed Effects	YES	YES	YES	YES
Sample	Entire Sample	Entire Sample	Traded and Litigated Patents	Traded and Litigated Patents
Patents	299356	299356	569	569
Observations	2436649	2436649	6,810	6,810
INSTRUMENT	Probit estimate of the probability of not being owned by the original inventor	OLS estimate of the probability of not being owned by the original inventor	Probit estimate of the probability of not being owned by the original inventor	OLS estimate of the probability of not being owned by the original inventor

NOTES: Standard errors clustered at patent level are reported in parentheses. Statistical significance: *10%, **5%, *** 1%. Litigation Dummy = 1 if the patent is involved in at least one case at that age; NewOwner = 1 when the patent changes ownership for the first time and remains equal to one for the remaining life of the patent. Time Period Dummies: before 1985, 1985-1990, 1991-1994, after 1995. Income Tax Rate: sum of federal and state income tax rates in state of first inventor.

TABLE 5: The Roles of Buyer Portofolio Size and Patent Fit - Instrumental Variable Estimation

	1	2	3	4	5
Estimation Method	**2SLS**	**2SLS**	**2SLS**	**2SLS**	**2SLS**
Dependent Variable	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**
NewOwner	0.338***	-0.248***	-0.491**	-0.302	-0.210***
	(0.11)	(0.08)	(0.24)	(0.22)	(0.08)
NewOwner x LargeBuyer					-0.368**
					(0.19)
NewOwner x TechFit					0.431***
					(0.13)
Age Dummies	YES	YES	YES	YES	YES
Time Period Dummies	YES	YES	YES	YES	YES
Patent Fixed Effects	YES	YES	YES	YES	YES
Sample	Traded and Litigated Patents: trade to small buyers and high patent fit	Traded and Litigated Patents: trade to small buyers and low patent fit	Traded and Litigated Patents: trade to large buyers and low patent fit	Traded and Litigated Patents: trade to large buyers and high patent fit	Traded and Litigated Patents
Observations	1585	4361	507	357	6810
Patents	116	382	47	24	569

NOTES: Standard errors clustered at patent level are reported in parentheses. Statistical significance: *10%, **5%, *** 1%. Litigation Dummy = 1 if the patent is involved in at least one case at that age; NewOwner = 1 when the patent changes ownership for the first time and remains equal to one for the remaining life of the patent. Time Period Dummies: before 1985, 1985-1990, 1991-1994, after 1995. LargeBuyer=1 if acquirer obtained more than 8 patents in the 20 years before trade. TechFit=1 if acquired patent belongs to technology sub-category in which buyer has more patents. NewOwner and its interactions are instrumented by the Probit estimates of the probability of not being owned by the original inventor.

TABLE 6: The Roles of Buyer Portofolio Size and Patent Fit - Robustness

	1	2	3	4
Estimation Method	**2SLS**	**2SLS**	**2SLS**	**2SLS**
Dependent Variable	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**	**Litigation Dummy**
	LargeBuyer =1 if more than 12 patents	***TechFit=0 if trade among individuals***	***TechFit constructed with narrow technology classes***	***TechFit defined using patent citations***
NewOwner	-0.221***	-0.130**	-0.190**	-0.227***
	(0.08)	(0.06)	(0.08)	(0.08)
NewOwner x LargeBuyer	-0.394*	-0.338*	-0.343*	-0.401**
	(0.22)	(0.19)	(0.19)	(0.20)
NewOwner x TechFit	0.450***	0.133***	0.383***	0.484***
	(0.13)	(0.04)	(0.14)	(0.13)
Age Dummies	YES	YES	YES	YES
Time Period Dummies	YES	YES	YES	YES
Patent Fixed Effects	YES	YES	YES	YES
Sample	Traded and Litigated Patents	Traded and Litigated Patents	Traded and Litigated Patents	Traded and Litigated Patents
Observations	6810	6810	6810	6810
Patents	569	569	569	569

NOTES: Standard errors clustered at patent level are reported in parentheses. Statistical significance: *10%, **5%, *** 1%. Litigation Dummy = 1 if the patent is involved in at least one case at that age; NewOwner = 1 when the patent changes ownership for the first time and remains equal to one for the remaining life of the patent. Time Period Dummies: before 1985, 1985-1990, 1991-1994, after 1995. In columns 2 to 4 LargeBuyer=1 if acquirer obtained more than 8 patents in the 20 years before trade. In columns 1 and 2 TechFit=1 if acquired patent belongs to technology sub-category in which buyer has more patents. In column 3 TechFit constructed using USPTO patent nclasses. In column 4 TechFit=1 if either the acquired patent cites one of the patents of the buyer or if the patents of the buyer cite the acquired patent. NewOwner and its interactions are instrumented by the Probit estimates of the probability of not being owned by the original inventor.

TABLE 7: Effect of Capital Gain Taxes on Frequency of Patent Trade and Litigation

Scenario	**Capital Gains Taxes (in percentage)**	**Traded Patents per 1000 patents**	**Predicted Suits per 1000 patents**
Baseline	29.2	56.9	36.1
Low Tax	20	94.3	22.5
High Tax	40	30.1	45.7
Capital Gains Tax = Income Tax	42.6	25.6	47.4
Capital Gains Tax = Income Tax	29.2	35.1	43.9

FIGURE 1. Trade and Likelihood of Litigation

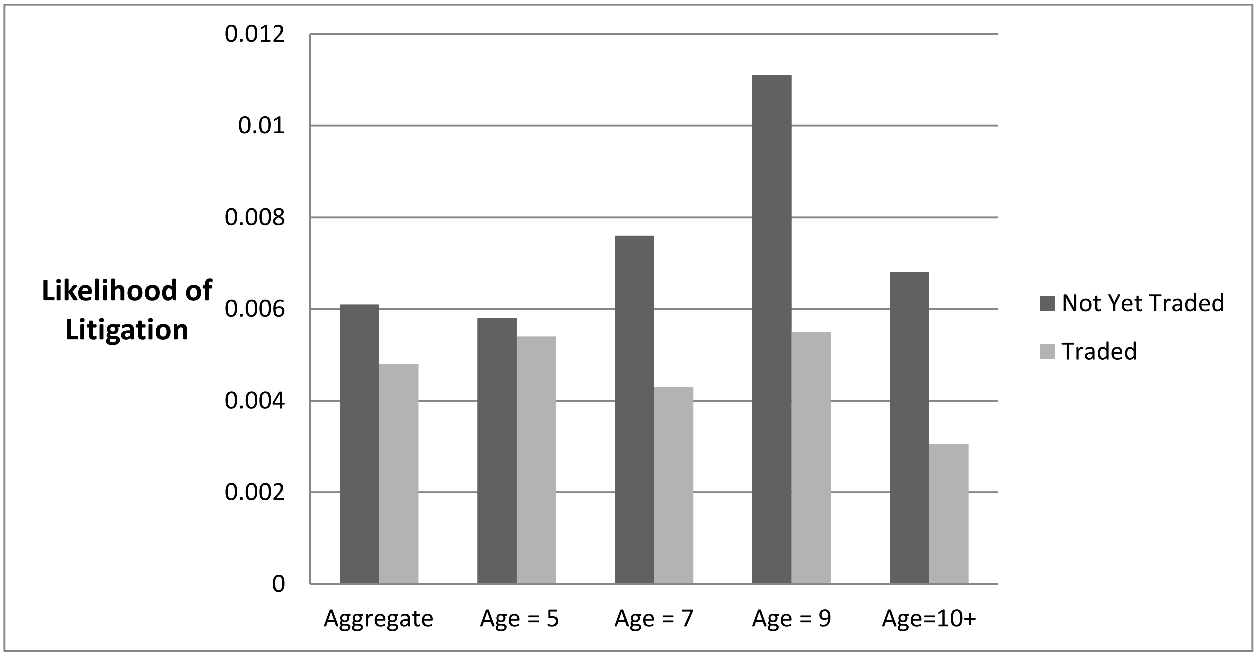

FIGURE 2. Marginal Treatment Effect- Entire Sample

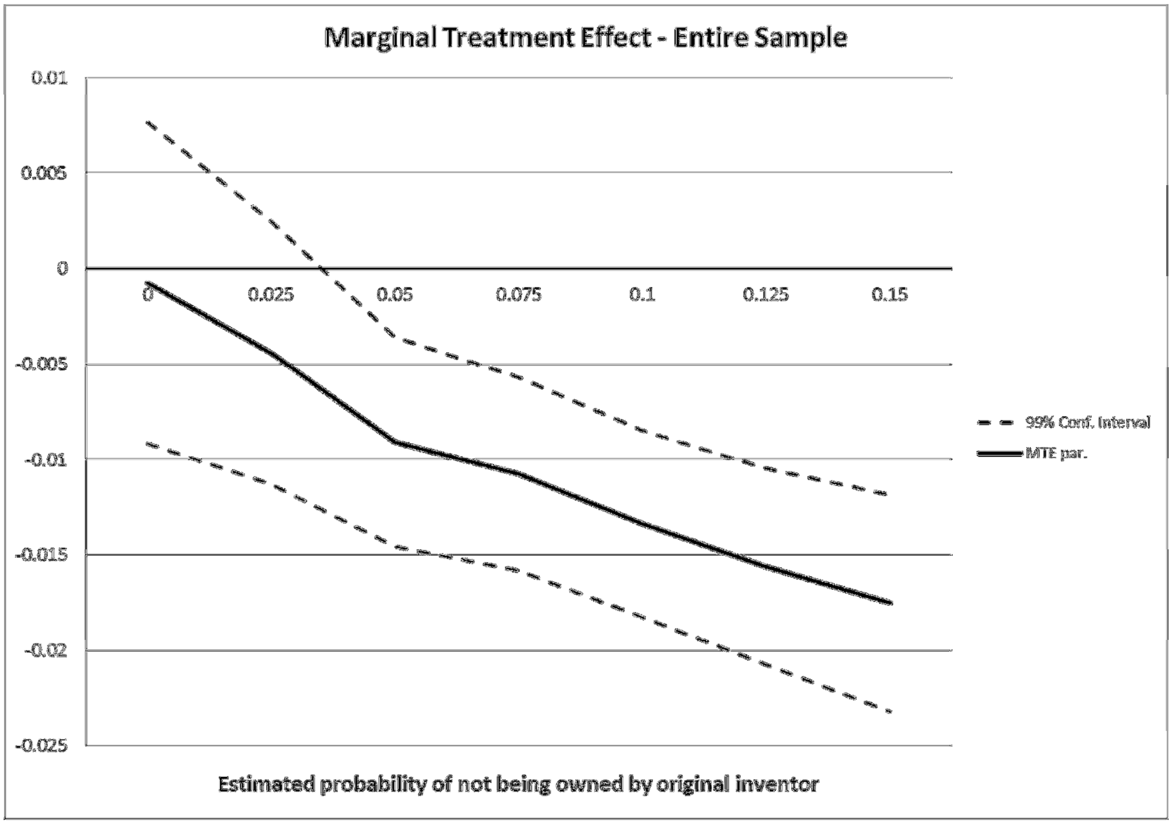

FIGURE 3. Marginal Treatment Effect – Litigated and Traded Patents