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The Dynamics of the Transfer and Renewal of Patents

Carlos J. Serrano*

University of Toronto and NBER

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Abstract

This paper presents new empirical evidence on the transfer and renewal of U.S. patents. We find that individual inventors and small innovators are the most intensive sellers of patents, while government agencies and large innovators are the least. Patents from categories such as computer and communications, drugs and medical, and electricity and electronics are the most likely to be traded. Both the probability of a patent being traded and the probability of being renewed is increasing with the number of total citations received by a given age and with patent generality. Furthermore, the probability of a patent being traded decreases with age except the year after a renewal date, which discontinuously increases. And previously traded patents, and especially the recently traded, are more likely to be traded and less likely to be allowed to expire than patents not previously traded. Finally, we analyze and interpret this new evidence using a theoretical model of patent transfers and renewal.

1 Introduction

The benefits of a well developed market for technology can be substantial. The market facilitates the diffusion of existing ideas; the creation of news ones; and it permits a more efficient use of economic resources, allowing incumbents and new entrants to specialize in what they excel. The market for technology has also important economic policy implications. For instance, to the extent that this market confers efficiency gains, these benefits

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could potentially offset concerns about inefficiencies associated to the patent system such as the grant of monopoly rights. Furthermore, when innovation is cumulative it matters who owns the intellectual property rights, the incentives on research of subsequent inventors might be affected by the willingness to license or sell the patents when innovating around them is difficult. Despite these policy implications and the importance of the generation and diffusion of technologies to economic growth, the empirical studies on these dynamic processes are few because the literature has been hampered by a lack of comprehensive data on how intellectual property assets are traded.[1] This paper addresses this issue by developing a new data set of the transfer of patents.

The primary objective of the paper is to present some patterns underlying the new data set. The data set has been constructed using the individual assignment records in the Patent Assignments Database at the United States Patent and Trademark Office (USPTO). This data contains information on the patent numbers being assigned to other entities as well as information concerning its rational, allowing us to identify the changes in the ownership of patents. We have obtained these records, converted them to the patent level, and merged them to existing data on the renewal status of patents, the number of patent citations received, the patent category (i.e., technology field), the generality of a patent, and the type of patentees as of the grant data of the patent. The new data set contains all U.S. patent granted from 1983 to 2001 and describes their history of transfers and renewal decisions. The transfer data makes a contribution adding a new dynamic component to the existing data work on patents.

The empirical regularities we present focus on two aspects. We first look at the intensity of patent trading by the type of patentees and patent categories. This allows us to learn something about where patent trading and the degree of specialization in research is likely to be more important. We find large differences across patentees, having individual private inventors and small innovators as the most active sellers, while government agencies and large innovators are the least active ones.[2] There is also some variation across patent categories in the average rates of transfer and renewal; and in some patent categories, the intensity of patent trading by type of patentee can be very different than in others.

The second aspect we explore is whether there exist observable patent characteristics that are significant determinants of the trading and renewal decision. In particular, we look at the age of the patent, its importance as measured by the total number of citations

[1] Important studies using licensing or survey data are Anand and Khanna [4]; Arora [8]; Arora, Fosfuri, and Gambardella [9]; Lerner and Merges [39], etc.

[2] Small innovator patents are those that are issued to firms that were granted no more than 5 patents in a given year. Similarly, large innovator patents are those issued to firms that were granted more than 100 patents in a given year.

received by a given age, and the patent generality or broadness (as defined in Hall, Jaffe and Tratjenberg [24]). This can help us understand better what patents are more likely to be sold and how quickly this occurs over the life cycle of a patent. We find a number of patterns. First, among patents of the same age, the probability of being traded and the probability of being renewed is increasing in the number of total citations received by a given age. Second, the probability of being traded and the probability of being renewed is increasing with the patent generality. Third, previously traded patents, and especially the recently traded, are more likely to be retraded and less likely to be allowed to expire than the ones not previously traded. Finally, the number of patents traded among active patents decreases with age except at the renewal dates. The year immediately after a renewal date, this rate discontinuously increases. These patterns describe the transfer and renewal of patents based on the size of their innovators, their technology field, and other characteristics such as their broadness, importance and age.

There are several reasons to study the transfer data and the workings of the market for patents. First, the patterns can provide some guidance in the assessment of existing models of intellectual property transfer and in the development of new ones. Second, the data can be used to study the sources of innovation and the diffusion of technology, which are significant determinants of long-run economic growth. Third, understanding the degree of specialization in research, the size of the market and the gains from trade in patents matter for determining policies towards innovation, mergers and taxation of intellectual property transfer. Fourth, when innovation is cumulative it matters who owns the intellectual property rights. The incentives on research of subsequent inventors might be affected by the willingness to license or sell the patents when innovating around them is difficult (Merges and Nelson [43], Scotchmer [54], Gallini [18], Green and Scotchmer [21], etc.). A final motivation is that the link of the transfer data to firm's characteristics can open new research opportunities for scholars. For instance, to study the process of specialization in research, the geography of the transfer of technology, the interplay between the firm's internal organizational structure of research activities and the market for intellectual property, etc. These issues are of interest because they matter for determining economic policy and the business strategy of firms.

To understand the empirical regularities in the data, we use an extension of the patent renewal model of Pakes and Schankerman [45] [51] developed by Serrano [55]. The framework in Pakes and Schankerman relies on heterogeneity in the economic value of inventions and a fixed cost that owners must pay to keep a patent active. The new model allows for the transfer of patents and adds two key features. First, it considers that some firms might be more productive than others in the use of a given patent, which implies that there may exist potential gains from reallocating patents to other firms. For instance, potential buyers might have complementary assets, better production facilities or managerial skills. Second, it assumes that adopting a technology developed by others involves a fixed cost. This cost might represent a new organizational design by the acquiring firm, the hiring of new engineers, new R&D, etc. In summary, whereas Pakes and Schankerman's model has one margin, should the patent owner pay the fee for renewing the patent, the model we use has a second margin, should the cost of technology adoption be covered to reallocate the patent to an alternative owner.[3]

1.1 Related Literature

Empirical work on the transfer of technology has been generally difficult due to a lack of comprehensive data on how intellectual property assets are traded. Previous studies have adopted two styles. The first one has used data on strategic alliances to explore the incidence of licensing, the timing and exclusivity of contracts and the determinants of control rights (Arora [8]; Lerner and Merges [39]; Anand and Khanna [4]; Arora, Fosfuri and Gambardella [9], etc.). The main disadvantages of this data are that the specific technology and patents licensed are not well identified, the transactions cannot be linked systematically to patent data, most licensing agreements are not publicly reported, and there is no information concerning the universe of technologies that could have been transferred. The second style relies on data from universities' technology transfer offices. This approach has studied the instruments by which knowledge is transferred (i.e., patents, journal publications, etc.), the role of geographic proximity and knowledge spillovers, and the interactions between firms and university researchers (Agrawal and Henderson [3], Branstetter and Ogura [13], Jaffe [28], Jaffe, Tratjenberg and Henderson [29], Jaffe and Tratjenberg [30], Sampat and Ziedonis [50]. While the latter approach uses more detailed data on the technology being transferred, the generality of the studies is limited to specific universities, geographical areas, etc.

The importance of licensing and strategic alliances as a technology transfer mechanism is well recognized, less known is the fact that patents are sold over their life cycle. The

[3] The model does not consider a number of important issues such as strategic considerations, asymmetry of information, the design and use of incentives in contracts of technology transfer, the demand for liquidity, etc.. Katz and Shapiro [33], Gallini and Winter [19], and Shepard [56] consider the transfer of technology as a strategic decision. Anton and Yao [6] [7] study markets where the inventors have an information advantage with respect to the value of the technology and sellers are reluctant to disclosure the idea because buyers may steal it without paying for it (Arrow [10]). Other scholars have analyzed the design of licensing contracts in terms of incentives (Aghion and Tirole [2] and Arora [8]; and recently Silveira and Wright [57] develop a model of the interplay between the demand for liquidity and the market for ideas.

main difference between the licensing and the transfer of patents is that while the former constitutes a permission of use or a promise by the licensor not to sue the licensee, the latter involves the transfer by a party of its right, title, and interest in a patent. The transfer data is particularly interesting for empirical work because the USPTO maintains public records of patent transactions that contain the specific patent numbers being assigned and the rational of the transfer. Surprisingly, there is very little work using patent assignment data. To the best of our knowledge, Lamoreaux and Sokoloff [36][37] and this paper are the only ones that explore this concept to study markets for technology. They use a sample of sales of patents of private inventors and provide a historical account of whether organized markets for technology existed in the late 19th and early 20th century.[4]

There exist, however, a very extensive empirical body of work in economics using patent data. Schmookler [52], Scherer [53], and Griliches [23] first related patent counts to industry classes and to firm characteristics. Pakes and Schankerman [45] [51] estimated the value of patents using aggregate renewal data. Pakes [44] generalized it to allow for learning and stochastic returns. Lanjouw [34] extended Pakes by considering patent infringement, and Putnam [48] used multi-country patent applications. Tratjenberg [59] pioneered the use of patent citations as a measure of economic value. Harhoff, Narin, Scherer and Vopel [26] studied the distribution of patent value and its relationship with citations using survey data from German and U.S. patents. More recently, Hall, Jaffe, and Tratjenberg [24], have created a database of all U.S. patents granted in the last four decades and their citations.[5]

The paper also relates to the industrial organization literature. There are several studies that have explored the relationship between business transfers and exit with the age and quality of the business[6]. Furthermore, other empirical works have explored the sale of businesses, mergers, asset sales and reallocation.[7]

The paper is organized as follows. Section 2 presents the model. Section 3 explains the characteristics of the new data, while section 4 documents the patterns. Section 5 concludes the paper. Finally, the appendix covers the details of the data construction.

[4] They present evidence that a number of services such as law firms and advertising magazines to assist in the transfer of patents was created during those years (i.e., prior to the growth of in-house R&D laboratories by large firms).

[5] The database has spurred a large number of research projects on innovation, spillovers and patents. For instance, Trajtenberg, Jaffe, and Henderson [60] study the "basicness" of invention in corporations and universities; Hall, Jaffe and Tratjenberg [25] analyze the relationship of the market value of corporations and patent citations; and Leiva [38] to develops a model of the value of patents and citations, etc.

[6] For instance, Evans [17]; Dunne, Roberts, and Samuelson [16]; Pakes and Ericson [47]; Holmes and Schmitz [27], etc.

[7] Some of them are respectively, Lichtenberg and Siegel[40]; Ravenscraft and Scherer [49]), Mitchell and Mulherin [42]; Andrade and Stafford [5]; Graff, Rausser and Small [20]; Maksimovic and Phillips [41]; Jovanovic and Rousseau [31] [32].

2 A Model of Patent Transfers and Renewals

This is an organizing framework for understanding some of the empirical regularities that we will present later. The model in this paper is based on the theoretical model of the transfer and renewal of patents developed by Serrano [55].

Serrano extends Pakes and Schankerman [45] [51]'s framework allowing for the transfer of patents. Pakes and Schankerman examines the problem of a patent owner deciding in each period whether or not to pay a renewal fee and thereby extend the life of a patent in a context with heterogeneity in the economic value of inventions. Building on this context, Serrano considers that patents might be traded because some firms are more productive than others in the use of a given patent, but to transfer a patent and adopt it to a new use involves a fixed cost to be paid by the buyer.[8]

To capture this trade off, consider the owner of a patent of age a with current revenue x at the beginning of a period. A random draw g^e taken from a cdf F_{g^e} determines the revenue of the best potential buyer, $y = g^e x$. The improvement factor $g^e \geq 0$ reflects that a potential buyer might generate higher revenue owning the patent than the current owner, maybe because of complementary assets, better production facilities, managerial skills, etc. The patent will be sold if the improvement factor of the potential buyer is large enough so that the fixed sunk cost of adopting the technology, τ, can be amortized over time. Furthermore, the higher the revenue x is, the lower the improvement factor g^e needed by a potential buyer to amortize the cost of adoption; and consequently the higher the probability that a patent will be sold. The reason is that the capacity to amortize the cost depends on the difference between the revenues of the potential buyer and the current owner; and for a fixed g^e, this difference increases with the revenue of the current owner. On the other hand, an older patent with the same revenue x will be less likely to be sold because a higher improvement factor is needed to amortize the cost of adoption when the patent horizon is shorter.

More formally, let $V_a(x, g^e)$ be the beginning of a period discounted value of a patent of age a, with revenue x if kept by current owner, and with an improvement factor g^e.

$$V_a(x, g^e) = \max\{0, V_a^K(x, g^e), V_a^S(x, g^e)\} \qquad a = 1, ..., L$$

where L is the maximum legal length of patent protection, 0 is the value of letting the patent expire; and $V_a^K(x, g^e)$ and $V_a^S(x, g^e)$ are the value of keeping or selling the patent,

[8] There is little evidence on estimates of costs of technology transfer. Åstebro [11] studies the adoption of both CAD and CNC technologies and finds that there are large fixed noncapital and capital costs of adoption.

respectively. For simplicity, we consider that the seller gets all the surplus.[9] These values are defined as the sum of the revenue of a patent of age a and the option value of keeping, sell or let the patent expire at age $a+1$ minus the patent renewal fee c_a at age a :

$$\begin{aligned} V_a^K(x, g^e) &= x - c_a + \beta E_{g^e}[V_{a+1}(x', g^{e\prime}|x, a)] \\ V_a^S(x, g^e) &= y - c_a - \tau + \beta E_{g^e}[V_{a+1}(x', g^{e\prime}|y, a)] \end{aligned}$$

where $\beta \in (0,1)$ is the discount factor, $E_{g^e}[.]$ is the expectation operator over g^e. We assume that between periods the patent revenue depreciates deterministically at a fixed rate $\delta \in (0,1)$ like in Pakes and Schankerman. This implies that $x' = \delta x$ if the patent is kept, and $x' = \delta y$ if sold.

Serrano [55] shows that in this model there exist functions $\widehat{g}_a^e(x, \tau)$ and $\widehat{x}_a(\tau)$ that divide the policy space into three areas (keep, sell and let the patent expire) as illustrated in Figure 1. The cutoff $\widehat{g}_a^e(x, \tau)$ is the improvement factor that makes a patent owner indifferent between selling a patent with revenue x and age a or not. For a fixed x and a, at $\widehat{g}_a^e(x, \tau)$ the cost of adopting the technology by the potential buyer is just amortized. If the improvement is above the cutoff, then the patent will be sold. For sufficiently low improvements, the revenue $\widehat{x}_a$ makes the owner indifferent between keeping the patent or letting it expire (like in Pakes and Schankerman). In this case, patents with lower revenues than $\widehat{x}_a$ are let to expire.

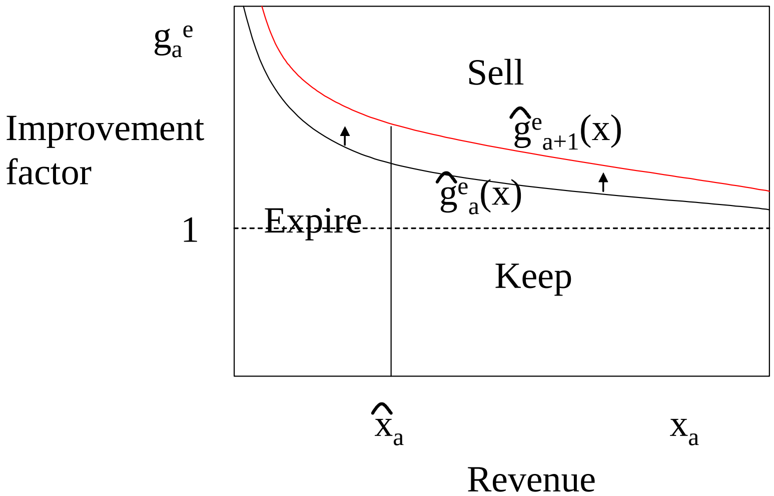
Note that the economic process we model considers that buyers of patents are adopters and users of the acquired technology rather than firms exclusively managing patents. The licensing of patents, however, is a real phenomenon and the model accommodates that patent owners might benefit from doing so.[10] To account for this possibility, we assume that the revenue of a patent represents both the proceeds of adopting and using a technology as well as the ones that the buyer could additionally obtain by licensing the patent.[11]

[9]We assume that the seller gets all the future expected proceed by the buyer. Similar qualitative results in the properties of the cutoff rules that solve the maximization problem can be obtained when the surplus is divided between the seller and buyer as long as the sharing rule is efficient.

[10]There is no systematic data on patent licensing revenue, but there exist some anecdotal evidence. IBM's licensing revenue was $1.6 billion in year 2000 (Berman [12]) as reported in Merrill, Levin and Myers [58]. In 1996 U.S. corporations received $66 billion in income from royalties of unaffiliated entities (Degnan [15]). Texas instruments reported to have obtained $1.6 billion in licensing royalties from 1996 to 2003 (Grindley and Teece [22]).

[11]In principle, what we consider is conceptually rather different than allowing a firm to specialize in managing a patent. For instance, a firm could exclusively focus on managing a patent by licensing it to many others who can then adopt it. Firms exclusively managing patents is a rather new organizational form mainly associated with firms acquiring patents for prospective litigation purposes.

Figure 1: The Policy Space



2.1 Predictions of the Model

The model predicts that if the cost of adopting a patent is positive then both the age of the patent and its revenue will affect the probability of a patent being traded. Some specifics predictions can be obtained:

Prediction 1: *The probability of an active patent being traded decreases with age.*

Prediction 1 holds because for a fixed x, the function $\widehat{g}^e_a(x,\tau)$ is increasing with the age of the patent, a. The intuition is that a shorter horizon implies less time to amortize the cost of adopting a technology. As a result, as a patent with a fixed revenue x gets older, the owners must meet better potential buyers in order to be indifferent between selling the patent or not. We call this the *horizon effect.*

Prediction 2: *The probability of an active patent being traded increases with its revenue.*

This result is equivalent to having the function $\widehat{g}^e_a(x,\tau)$ decrease with x for a fixed a. That is, the higher the revenue x is, the lower the improvement g^e needed for the costs of adopting a technology to be amortized; or in other words, for the owner of the patent to be indifferent between selling it or not. The intuition is that given an improvement factor g^e, since the revenue of the potential buyer y is proportional to the one of the current owner x; the higher is x, the larger the difference between the two revenues as well as the difference between the value of selling and keeping the patent. Consequently, the higher is x, the easier to amortize the fixed cost of technology adoption and then the lower is the cutoff

$\widehat{g}_a^e(x, \tau)$ that makes an owner indifferent between selling the patent or not. We call this the *selection effect*.

Figure 1 shows the shape of the cutoff rule $\widehat{g}_a^e(x, \tau)$ as a function of both x and a. The selection and horizon effect, as represented by $\widehat{g}_a^e(x, \tau)$ int the figure, hold because the fixed cost of adopting a technology is positive rather than zero. These results allow us to learn something about why, how fast, what types of patents are traded, and the implications of the importance of sunk costs of adopting a technology in the market for patents.[12]

Some predictions on the trading and expiring for previously traded patents can also be derived from the model:

Prediction 3: *Traded patents are more likely to be retraded than not previously traded patents.*

The model indicates that since traded patents are on average patents with higher revenues, then they are less likely to be allowed to expire.

Prediction 4: *Traded patents are less likely to be allowed to expire than not previously traded patents.*

Similarly, since traded patents are on average patents with higher revenues, then the selection effect implies that conditional on age they are more likely to be traded.

Prediction 5: *Recently traded patents are more likely to be traded and less likely to be allowed to expire than the no recently traded ones.*

For the same reasons, since patents that were traded recently have on average higher revenues than the ones not recently traded, then the selection effect implies that they are more likely to be traded than patents not recently traded.

Another interesting implication of the model is the interaction of the effects of the renewal dates with the probability of a patent being traded. This feature appears when mandatory renewal fees are not due at every age, i.e., like in the U.S. system.[13]

[12]There several key elements that allows Serrano to prove the results. One is that the cost of adopting a technology is fixed and does not fully internalize how the difference between the value of selling or not a patent changes as the revenue and age of the patent varies. Another important element of the structure of the model is that the improvement factor g^e is independent of the age and revenue of the patent. This simplifies the process g^e and implies that the buyer's per period patent revenue depends on the revenue of the current owner. If the revenue of the potential buyer was independent of the revenue of the current owner, then neither the selection nor the horizon effect would hold in general.

[13]In the U.S. patent system mandatory renewal patent fees are due at the end of the 4th, 8th and 12th year. If the fees are not paid, then the patent expires.

Prediction 6: *The probability of an active patent being traded increases immediately after a renewal date.*

The model predicts that two opposing forces determine the level of this probability in the year after a renewal date. It is useful to describe the two forces in detail. On the one hand, the probability of an active patent being traded the year after a renewal date might increase because since the patents with lowest revenue are let to expire, the remaining active patents have higher average revenue *immediately* after a renewal date than the average revenue of the patents right before the same date.[14] This feature implies a discontinuous jump of the probability of an active patent being traded *immediately* after a renewal date because of sample selection and the selection effect. On the other one, the probability might decrease because over the year after a renewal date the revenue of patents depreciate and their age increases. If the revenue is lower, then the selection effect implies that the probability of a patent being traded is lower as well. Similarly, if the age increases, then the probability of a patent being traded decreases because of the horizon effect. Hence, if the first force dominates, then we should observe a discontinuous jump in the empirical probability of a patent being traded the year after a renewal date.

3 Measuring Transfer of Technology with the USPTO Assignment Data

There are some two key aspects that makes the assignment data particularly interesting for empirical work. First, when a U.S. patent is sold, the buyer may record the change in ownership at the USPTO. Second, a recordation of a patent transaction contains the patent numbers being transferred as well as information concerning the rational of the transfer. These aspects allow us to explore a number of questions: what type of patentees and in what industries patent trading is likely to be more important, the patent life cycle effects in the transfer of patents, the importance and the generality of the patent being transferred, etc.

The rest of the section is divided into four parts. First, we discuss the contents of the assignment data base we use to create the new data set of the transfer of patents. Second, the general principles that led to the decision made in the construction of the data. Third, the description of the sample selection we focus on. Fourth, the contents of the new data set.

[14] An implication of the fact that in the model the distribution of per period revenue immediately after a renewal decision stochastically dominates the distribution of revenue prior to the renewal date.

Original assignment data. The main source of our data is the USPTO Patent Assignment Database. When a U.S. patent or a bundle of them are transferred, an assignment may be recorded at the USPTO acknowledging the transfer by a party of the rights, title and interest in a patent or bundle of patents. The USPTO maintains in electronic format all assignments recorded since August 1, 1980. A typical assignment is characterized by a unique identifier (i.e., reel frame), the name of the buyer (i.e., assignee) and the seller (i.e., assignor), the date that the assignment was recorded at the patent office (i.e., recorded date), the date the private between the parties was signed (i.e., execute or signed date), the number of patents or patent applications included in the assignments, and the type of the assignment acknowledging the rational of the transfer (i.e., brief).[15] We have obtained these records in a daily basis until December 31, 2001.

The most recorded type of assignment in the data base represents the transfer of ownership from one entity to another (i.e., assignment of assignors). An assignment of assignors that is a first assignment tends to take place within the firm at which the original inventor of the patent works.[16] Instead, assignment of assignors that are subsequent assignments or reassignments represent the transfer of the ownership of patents across firm boundaries. While assignment of assignors is the most common transaction, assignments can also be recorded to acknowledge the union of two or more commercial interests (i.e., mergers); when a patent is used as collateral (i.e., security interest); a change of name of the firm that owns the patent or patent application (i.e., change of name); as a correction of a previous record (i.e., pro nunc tunc), etc.

Data construction. We will describe here the three main general principles that led to the decisions made in the construction of the data set; the details of the procedures we use to deal with the transfer data are explained in the appendix of this paper. First, the interest of the new data ultimately lies on the reallocation of the ownership of patents for technological purposes. The assignment data allows us to identify and separate assignments recorded as administrative events such as a name change, a security interest, a correction, etc.

Second, we should focus on transaction of patents across firm boundaries. We identify whether a recordation of a transaction is a first assignment or a reassignment using the name of the patent inventors and the assignee as of the grant date of the patent. When

[15] Unfortunately, the names of the buyer and seller in the Patent Assignment Data Base were never standarized by the USPTO.

[16] The U.S. patent law mandates that patents rights first belong to their inventor unless assigned to others. For this reason, it is common in labor contracts to specify that employees must assign the rights of their inventions to the firm or organization in which they work.

assignees as of the grant date of the patent are firms or government agencies, we exclude first assignements. Alternatively, if patents are individually owned as of the grant date, then we consider the assignment a patent transfer. For future reference, we define "trades" or "transfers" as reallocations of patents across firm boundaries.

Third, we linked the assignment records at the patent level to existing patent data on patent renewals, citations, generality, technology field, the name of the assignee as of the grant date of the patent, and other patent characteristics. The information on patent technology field, citations, generality and the name of the assignee as of the grant date of the patent can be obtained from the NBER Patent Database for patent granted from January 1, 1975 to December 31, 2002 . The renewal information is based on information from the USPTO Patent Renewal Fees Data Base as of December 31, 2002. The data contains the renewal status of patents subject to renewal fees.

Sample selection. The selection is based on a number of patents and patentees characteristics as of the grant date of the patent. First, we focus on patents that are subject to renewal fees.[17] and that were granted since January 1, 1983. Patents subject to renewal fees are those applied for after December 12, 1980. Moreover, since on average the application period is about 2.5 years, we use patents granted since January 1, 1983 to create a comprehensive data set.

Second, we consider utility patents and exclude patent applications. Utility patents represent the most common type of patent. Patent applications are not included because we have no information about applications that were not granted.

Third, the time unit of analysis of the new data set is the age year of a patent. In principle, a patent while active can be traded at any date. In our empirical analysis, however, we consider that a patent is traded in a given year if it was traded at least once over that period.

Finally, when studying patent transfers, one must recognize that patents that are traded in large blocks might not represent technology transfers. For instance, the merger between two large companies[18]. Obviously, in a wholesale trade of thousands of patents, the decision making is not uniquely at the level of a single patent or necessarily driven by the

[17]In the U.S. patent system, the maximum possible term of an issued patent (assuming that any required renewal fees are paid) was 17 years from the grant date for patents applied for before June 8, 1996. The maximum term is 20 years from the filing date for utility patents applied for on or after June 8, 1996. In the U.S. patent system, patents applied for from December 12, 1980 are subject to renewal fees by the end of years 4, 8 and 12 since its grant date. If renewal fees are not paid, then the patents expire.

[18]For instance, when Burroughs Corporation merged with Sperry Corporation to create Unisys Corporation in September 1986, this event appears in the data as transactions totaling 2261 patents (the largest single transaction includes 1702 patents).

reallocation of technology.[19] While our empirical analysis studies all type of patentees, for the above reason and to parallel our focus in the theory, we focus especially on patents from *small innovators* (i.e., patents granted to firms with no more than five patents granted in a given year) and *individually owned patents* (i.e., patents granted to individual inventors and unassigned patents as of the grant date). In doing so, the economic forces that we highlight will be more salient than in transactions involving two very large corporations or patents owned by large corporations.[20] In addition, studying small innovators and individually owned patents is interesting in their own right, given the importance they play in the innovation process (Acs and Audretsch [1]; Arrow [10]).

Contents of the transfer data. The new data set is a panel of patents with their histories of trades and renewal decisions that took place up to the end of the year 2001.[21] Patents are categorized by their quality or importance, generality, the patentees, and when the patentee is a corporation with a measure of its the size as of the grant date of the patent. Summary statistics about granted and traded patents by type of patentee can be found in Table 4 in the appendix.

Every measure of patent quality or importance we can potentially use is going to be imperfect. We follow the previous literature and use citations received as such a measure. We consider that citations are correlated with the private value to patent protection, but they do not cause it. In particular, conditioning on the age of a patent, we assume that patents with higher number of total citations received have on average higher private value to patent protection. In practical terms, we use two terminologies that are associated to the number of patent citations received. We define *total citations received by a given age* as the sum of citations received from the grant year of the patent to the year it is up for trade or renewal. We define *total citations received by the maximum legal length of patent protection* as the sum of citations received from the grant date and until the maximum legal lenght of patent protection.[22]

[19]For instace, these transactions can be recorded as a result of large acquisitions pursued to increase the buyer's market share in a particular product or field, etc.

[20]For instance, we find that the proportion of patents traded in bundles of more than 100 patents, which were mostly developed by large firms, disproportionately increase in the periods of merger such as the mid-1980s wave and late 1990s. In addition, according to Mitchell and Mulherin [42], a substantial number of acquisitions in the wave of mid 1980's could be explained by major shocks such as deregulation, increased foreign competition, financial innovations, etc. We see these forces inherently different than those that predict the transfer of knowledge due to specialization, which is what we mean by economic forces.

[21]There are 20 cohorts coexisting in the unbalanced panel. For the case of non-censored cohorts (i.e., granted from 1983 to 1985).

[22]When the last year that a patent is observed in the panel is less than the maximum legal length, then we use the number of total citations received as of the last year the patent is observed. (i.e., a patent granted in 1990 will use the number of total citations received at age 11).

The generality variable and patent category are defined like in Hall, Jaffe and Trat-jenberg [24]. Generality measures whether the impact of a patent is broad. That is, conditional on total number of citations ever received, if a patent is cited by others that belong to a wide range of fields, then the generality variable will be high, while if most citations are concentrated in a few fields, then it will be low. This measure is interesting because it reflects the range of opportunities of applications, perhaps from potential buyers. The patent category variable aggregate patents into six different technology fields: chemicals; computer and communications; drugs and medical; electrical and electricity; mechanical; and other.

Finally, we consider six type of patentees or owners of patents as of their grant date. The type of patentees are individual private inventor patents, unassigned patents as of the grant date owned by the inventors; small, medium and large innovators; and government agencies.[23] When the owners are corporations or innovators, we can construct a measure of their size of firms based on the total number of patents granted in a given year. This allow us to match all the patents to patentees. While we would like to use standard measures of firm size like employees or assets, it is difficult to find such measures for all the patentees.

The new data makes a contribution adding a dynamic component, namely the transfer of patents, to the existing data work on patents. The data, however, is not without drawbacks. First, after a patent has been granted, the names of the first buyer, and subsequent sellers and buyers of the transactions are not standardized by the USPTO. Second, we cannot distinguish the acquisition of a firm from the acquisition of a bundle of patents.[24] Third, we do not have information on the price paid for the patents transferred. Fourth, the theory considers that patents are sold to potential buyers that adopt and use the technology. This is conceptually rather different than allowing a firm to exclusively focus on managing a patent by licensing it to many others who can then adopt it. In practical terms, the data on patent transfers possibly involves both types of transactions, but we cannot distinguish them. Firms exclusively managing patents, however, is a rather new organizational form mainly associated with firms acquiring patents for prospective litigation purposes. For this reason we expect that the majority of the transfers in the data set represent the adoption of a technology. Fifth, the reassignments data in electronic

[23] Small innovators patents are defined as those owned by corporations that were granted no more than 5 patents in a given year. Large innovators patents are those issued to corporations with more than 100 patents granted in a given year. Medium innovators patents are the rest.

[24] In the hypothetical case that a small innovator was acquired rather than a bundle of its patents, we consider that it might be acquired mainly because of the value of its technological assets. In this scenario, the transfer will likely involve a cost of adopting and especially setting up the technology in the new firm. Thus, to some extent an acquisition of an innovative firm would be no necessarily different than the transfer of its patents.

format we have dates from August 1, 1981 to December 2001.

4 Patterns of the Transfer and Renewal of Patents

In this section we present ten patterns undelying the transfer and renewal rates by type of patentees, patent category, patent characteristics and over a patent life cycle. The first four patterns present the proportion of patents that are traded at least once over their life cycle and expired by age 13 dissaggregated by type of patentees and across patent categories. These rates will allow us to learn something about whom and in what technology fields patent trading is likely to be more important. The rest of the patterns identify a set of patent characteristics that are systematically related to the trading and the renewal decision; namely the total number of patent citations received by a given age, the patent generality, whether the patent has been previously traded and the timing of the last trade. These patterns can help us understand what type of patents are more likely to be sold and how quickly the change in ownership occurs over the life cycle of a patent.

Furthermore, we use a logit model to analyze the robustness of the patterns. The parametric analysis is useful because it allows us to control on a larger number of variables. There are two groups of regressions we present in the appendix. The first group considers all active patents and uses controls on age, patent category, patentee and citations. It is also useful to run a second group having each of the patentees in a separate regression.

Pattern #1: *The proportion of patents traded varies across patentees, and the proportion is higher when weighted by the total number of citations received by the legal maximum length of patent protection.*

Table 1A provides the disaggregated cumulative transfer rates during the life cycle of patents across patentees. These rates varie from a low 4.1% to a high of 17.5%. The average rate of transfer is 13.5%. The columns in the table correspond to each of the patentees. Small innovators and private inventors are the patentees that are more likely to sell their patents; followed by medium innovators, individual owned unassigned patents as of the grant date, large innovators and governments agencies. Among corporations, the rates of transfer decrease with the size of the firms. Furthermore, when weighted by the total number of citations received by the legal maximum length of a patent, the cummulative rates of transfer are higher.[25] The weighted rates vary from 6% to 24.1%.

[25]Similar results are obtained when the weighs are based on the total citations received by a given year, i.e., the year that a patent is up for trade or renewal.

Table 1: Proportion of Patents Traded and Expired by Type of Patentees

	Individual owners			Corporations (Innovators)				Govt. Agencies
	All	Unassigned	Priv. Inventors	All	Small	Medium	Large	
A. Proportion of patents traded over their life cycle by type of patentees								
Unweighed	12.4	12.2	16.2	14.0	17.5	14.6	10.5	4.1
Weighed by citations	19.0	18.7	24.1	17.2	24.0	17.4	11.4	6.0
B. Proportion of patents expired up to the last renewal fee by type of patentees								
Unweighed	77.5	77.7	73.1	55.1	60.3	55.5	50.0	83.5
Weighed by citations	68.4	68.9	62.0	43.2	48.8	42.8	39.1	74.4

Pattern #2: *The proportion of patents that are let to expire varies across patentees. The proportion is lower when weighted by the total number of citations received by the legal maximum length of patent protection.*

The cumulative expiration rates summarized in Table 1B also show a similar pattern. These rates.varie substantially from 50% to 83.5%, with an average of 59.5%. When weighted by total number of citations received by the maximum legal length of patent protection, the rates are lower and the variation increases from a low 39.9% to a high 74.4%. The table also shows that corporations are less likely to let their patents expire than individual owners and government agencies. And within corporations, small innovators are the ones most likely to let their patents expire while large innovators the least.

The robustness of the effects of the type of patentees in the trading and expiring decisions are studied by the inclusion of dummy variables in a logit model. We consider dummies for the type of patentees, patent categories and patent age. With this parametric model we can also control on the total number of patent citations received by a given age. Table 5, in the appendix, presents both the predicted probabilities of a patent being traded and expired by type of patentees constructed with the estimates of the logit model. The probabilities are evaluated at the at the mean of the sample of the patent categories and citations. The predicted cummulative rates of transfer varie from a low 4.1% to a high of 18.6%.

Pattern #3: *The proportion of patents traded varies across patent categories.*

Table 2A presents the cummulative transfer rates across patent categories. The six columns represent the aggregate technology fields in which patents are classified. The

Table 2: Proportion of Patents Traded and Expired by Patent Category

	Chemical	Computer & Comm	Drugs & Medical	Elec. & Electro.	Mechanical	Other
A. Proportion of patents traded over their life cycle by patent categories						
	14.9	12.9	16.0	13.8	12.0	13.1
B. Proportion of patents expired up to the last renewal fee by patent categories						
	60.0	47.3	57.4	55.1	61.7	67.9

rates varie from a low 12% to a high of 16%. The patents that are more likely to be traded are those belonging to the categories of computer and communications, drugs and medical, and electricity and electronics. Table 7A, in the appendix, summarizes the rates of transfer dissaggregated by patent categories and patentees. The variation across patent categories within a patentee tends to be larger than the average variation across patent categories.

Pattern #4: *The proportion of patents allowed to expire varies across patent categories.*

Table 2B presents the rates of expiration across patent categories by the last renewal date at age 13. The columns of the table correspond to the patent categories. The proportion of patents allowed to expire differ across patent categories from a low 47.3% to a high of 67.9%. Table 7B, in the appendix, presents the same information disaggregated by patentees. An interesting observation is that the differences across patent categories but within patentees are larger than their average rate of expiration.

While the differences in the rate of transfer and expiration across patent categories and patentees are significant, they could also depend on the patterns of patenting by patentees and the characteristics of their patents. To account for this possibility, we run logit models for both the trading and the expiring decision regressed on a number patent characteristics as controls. Like in the previous section, we use the total number citations received and dummies for the type of patentees, patent categories, and patent age. Table 6 presents the predicted cummulative probabilities of transfer and expiration by patent categories and patentees evaluated at the sample mean of the controls. The differences are now somewhat smaller, but the rates are similar.

It is also useful to look at in more detail the rates of transfer and expiration. Table 7, in the appendix, reports these rates across patentees and disaggregated by patent categories. The top part of the table presents the cumulative transfer rates and the bottom part the cumulative rates of expiration by age 13. The columns of the table are the patent

Table 3: Patents Traded and Expired for Small Innovators

A. Patents Traded as a Percentage of All Active Patents

			Previously Traded (Years since last trade)				
Age of Patent (Years)	All	Not Previously Traded	Any Year	1	2	3	4
1	2.505	-	-	-	-	-	-
2	2.335	2.225	5.287	5.287	-	-	-
3	2.201	2.068	4.753	5.265	4.244	-	-
4	2.179	2.007	4.453	5.043	4.291	4.025	-
5	2.220	1.989	4.407	5.324	4.527	3.840	3.769
6	2.017	1.753	4.068	4.935	4.127	3.765	4.103
7	1.902	1.621	3.805	4.963	3.750	3.796	3.567
8	1.885	1.565	3.801	4.962	3.860	4.075	3.595
9	1.937	1.566	3.789	4.825	3.162	3.915	3.878
10	1.779	1.404	3.494	3.839	3.369	4.825	3.221
11	1.676	1.354	3.042	3.937	3.618	3.671	2.836
12	1.540	1.264	2.626	3.276	3.851	2.537	2.411
13	1.675	1.331	2.868	2.001	2.273	4.721	3.280
14	1.680	1.330	2.847	3.234	2.774	4.513	4.070
15	1.362	1.008	2.497	2.802	2.189	2.698	3.0
16	1.157	0.861	2.075	2.229	1.559	3.817	1.439
17	0.841	0.607	1.566	1.818	1.181	2.821	1.976

B. Patents Expired as a Percentage of All Active Patents

			Previously Traded (Years since last trade)				
Age of Patent (Years)	All	Not Previously Traded	Any Year	1	2	3	4
5	18.399	18.958	12.707	6.696	12.148	14.456	16.08
9	29.143	30.077	24.087	11.253	18.650	22.070	23.407
13	33.014	34.131	28.830	15.515	22.663	24.280	29.614

categories and the rows are the type of patentees. The magnitude of the differences in the transfer rates between patentees varie when we examine patent categories separately, maybe indicating a different degree of patentee specialization in research across patent categories. For instance, table 7A shows that in the computer and communication category, small innovators transfer 23.9% of their patents while large innovators only sell 7.9% of theirs. But in the chemical category the sale rates are 17.2% and 12.5% for small and large innovators, respectively.

Pattern #5: *Active patents with a higher number of total citations received by a given renewal date are less likely to be allowed to expire.*

Table 8B, in the appendix, presents the estimates of regressing the decision whether to allow a patent to expire at a renewal date on the total number of citations received by the renewal date and a number of patent characteristics. The first column of this table presents estimates for the whole sample, while the rest of the columns contains the estimates that were obtained running separate regressions for each patentee. The rows of the table present estimates on citations for different sets of patent characteristics which include age dummies, patent category dummies and patentee dummies. The estimates of the number of total citations received by a given age are negative and statistically significant. A negative number indicates that patents with higher number of citations are less likely to be allowed to expire. For instance, using the estimates of the sample of small innovators that control on age and patent category and evaluating the predicted probabilities at the mean of the sample, an extra citation decreases the predicted probability of an active patent being allowed to expire at age 9 by about 1 percentage point, i.e., decresing from 30.6% to 29.7%.

Pattern #6: *Active patents with a higher number of total citations received by a given age are more likely to be traded.*

Table 8A, in the appendix, shows the estimates of regressing the decision to trade an active patent on a number of controls. The structure of this table is similar to table 8B. The sign of the estimates of citations is positive, implying that patents with more citations received by a given age are more likely to be traded.[26] The estimates are significant at standard levels and they are robust to a number of specifications. There is one exception, the regression for the sample of patents of large innovators.[27] Using the estimates from table 8A evaluating the predicted probabilities at the mean of the sample, we can calculate that an extra citation increases the predicted probability of an active patent being traded at age 7 by about 0.02 percentage points, i.e., increasing the rate from 1.92% to 1.94%.

Pattern #7: *Active patents with higher generality measures are more likely to be traded and less likely to expire.*

Table 10A and 10B, in the appendix, present respectively the estimates of both the regression of the probability of a patent being traded and the probability of a patent being alllowed to expire regressed on the generality measure and a number of controls. The first column of the table present the estimates of the whole data set, the rest of the columns

[26]Similar results are obtained when using the total number of citations received by the maximum legal length of patent protection.

[27]The negative coefficient of patent citations is based on patent that belong to patent category 4 (Electrical and electronics). In the rest of the categories, the coefficient is positive and significant or not statistically significant. Moreover, when we estimate the probability of a *granted* patent being traded using the same explanatory variables, the effect of citations is significant across patentees and robust to patent categories.

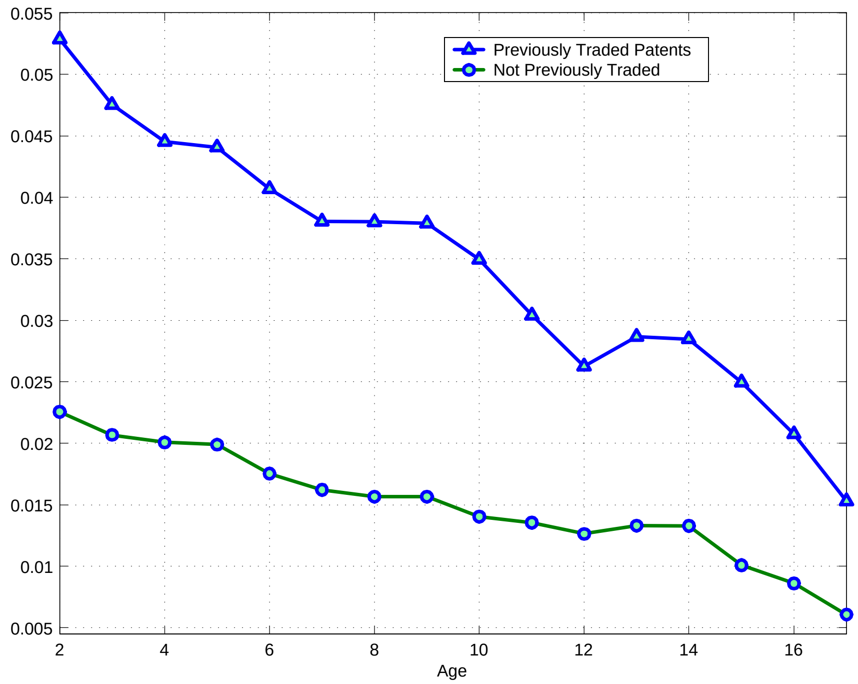
show the estimates of separate regressions for each type of patentee. The rows consider different set of patent characteristics. The estimates of generality are positive in the trading decision and negative in the expiring one. They are are statistically significant for every set of patent controls, i.e., age dummies, adding patent categories, adding citations, and the last one adding patentees.[28] When running a separate regression for each patentee, the result are consistent except for government agency patents. A positive coefficient in the trading decision implies that higher patent generality is associated with a higher probability of a patent being traded; a negative estimate in the expiring decision implies that patents with higher generality have a lower likelihood of being allowed to expire. For instance, a patent of age 7 with 0.1 extra units of generality than the mean increases its predicted probability of being traded from 2.00% to 2.04% when evaluated at the sample mean of the rest of the variables. Similarly, the probability of an active patent expiring at age 9 decreases from 27.8% to 27.5% with 0.1 extra units of generality.

Pattern #8: *Active previously traded patents of the same age, and in particular the recently traded, are more likely to be traded and less likely to be allowed to expire than patents not previously traded.*

Table 9, in the appendix, presents the estimates of both the probability of a patent being traded and the one of the probability of a patent being allowed to expired regressed on whether a patent has been previously traded and a number of controls. Table 11, in the appendix, shows the estimates of the same probabilities but now regressed on the number of years since the last trade and patent controls. The structure of these tables is similar to the previous ones. The estimates indicate that previously traded patents, and especially the recently traded, are more likely to be traded again and less likely to be allowed to expire. For instance, using estimates from table 9 and evaluating the predicted probabilities at the mean of the dummy variables, we can calculate that the predicted probability at age 7 of a patent being traded increases from 1.68% to 3.81% if it has been previoulsy traded. The probability of a patent being expired at age 9 decreases from 29.5% to 23.0% for previously traded patents. The results are significant at standard significance levels and robust to patent category and patentee dummies. When we run separate regressions for each patentee, the results are also statistically significant. There are few exceptions like patents of government agencies. Figure 2 shows the probability of an active small innovator patent being traded conditional on having been previously traded

[28]It is interesting that when adding citations to the previous controls, the coefficient estimate of generality in the expiring decision drops by about three times, but the one in the trading decision does not change much.

Figure 2: The Number of Patents Traded as a Proportion of Active Patents Conditional on Having Been Previously Traded or Not (Small Innovators)



or not. Furthermore, table 3 shows the proportion of patents traded conditional on the timing of the last trade for the sample of small innovators patents.[29]

Pattern #9: *The number of expired patents as a proportion of all active patents (i.e., the expiration rate) increases with the renewal dates.*

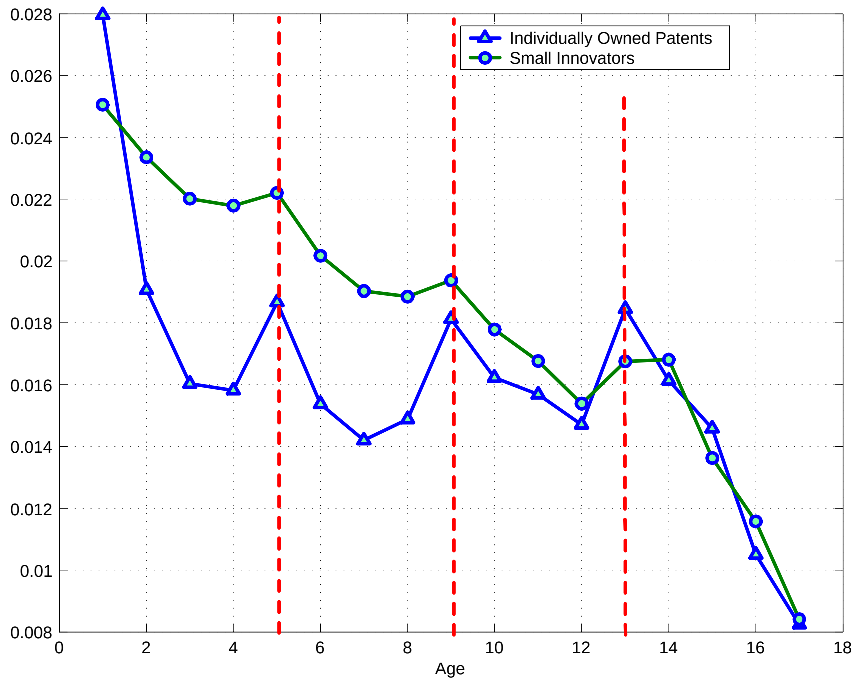
Table 3B shows that the expiration rate is increasing with the renewal dates for small innovator patents. The pattern is similar across type of patentees and it is significant and robust to patent category dummies. Table 5, in the appendix, presents the estimates.

Pattern #10: *The number of patents traded as a proportion of all active patents decreases with age except the years after a renewal date. The year after a renewal date, this rate discontinuously increases.*

Figure 3 shows the probability of an active patent being traded as a function of its age for both small innovator patents and individually owned patents. The decreasing

[29]The standard errors of the proportions in the table are omitted. They are very small because the number of observations is large.

Figure 3: The Number of Patents Traded as a Proportion of Active Patents (Small Innovators and Individual Owned Patents)



pattern is consistent across type of patentees and patent categories with the exception of large innovators. Table 12, 13, 14 and 15, in the appendix, show the estimates of the age dummies in regressions run with a number of controls. Using the estimates from the logit regressions with age dummies, we find that the jumps in the transfer rate are significant at standard significant levels for the sample of all patents and for individually owned patents (private inventors and unassigned patents), but for small innovators the jumps are significant but at somewhat higher significance levels.[30] The results are similar when patent category controls are used.[31]

[30]We test the following three null hypothesis for all the samples: *i*) age_year4≥age_year5; *ii*) age_year8≥age_year9; and *iii*) age_year12≥age_year13. If the p values are sufficiently low then, we can reject the hypothesis and conclude that the jumps are significant at a certain statistical significance level. We obtain the following p values. The first to last number in the parenthesis represent null hypothesis *i* to *iii*. All innovators (0.2819; 0.00; 0.00); Individually owned patents (0.00; 0.00; 0.00), unassigned (0.00; 0.00; 0.00), private inventors (0.0529; 0.0755; 0.03776), small innovators (0.140; 0.1468; 0.0308); medium innovators (0.9697; 0.0125; 0.00); large innovators (0.00; 0.00; 0.6461) and government agencies (0.777; 0.00; 0.4490). Similar results are obtained when the sample proportions are used instead of the age dummies.

[31]When we estimate the probability of a patent being traded on age dummies and total citations received by a given age, the jumps of the age dummies after a renewal date are smaller than when the variable total citations received by a given age is not included. To the extent that the number of total citations received

In addition, we have four remarks concerning the above patterns. First, renewal dates do not act as a signalling device in a context of asymmetry of information with respect to the value of patent protection. When we use the sample of patents that never expired, and look at the probability of a patent being traded, this probability does not discretely jumps the year after a renewal date. Second, when we condition on granted patents, the probability of a patent being traded decreases with age with no jumps in the year after a renewal date. Third, there are elements other than age and total citations received by a given age that affect the trading decision. We find that despite controlling for total citations received by a given age, previously traded patents are still more likely to be traded than the ones that were not previously traded. Fourth, total citations received are not a perfect measure of the value of patent protection. For instance, patents keep getting citations after their expiration date. Two reasons might be that citations are not contemporaneous with patent protection and that citations also represent spillovers.

5 Conclusion

This paper has used a newly constructed data set about the transfer of the ownership of patents to provide a summary of basic patterns of the transfer and renewal of patents.

We have explored a number of issues in the paper. The first aspect we have looked at is whether the intensity of patent trading differs by types of patentees and patent categories. We found that small innovators and private inventors are the most active sellers of patents, while government agencies and large innovators are the least. The number of patents traded as a proportion of all granted patents is a significant number, and it is higher when weighted by the importance of the patents as measured by their total number of citations received. Moreover, there are differences in the rates of transfer and renewal across patent categories, having computer and communications, drugs and medical, and electricity and electronics the most actively traded.

The second aspect we have analyzed are patent characteristics and life cycle properties of the transfer and renewal of patents. We have found a number of patterns. First, among patents of the same age, we showed that those with a higher number of total citations received by a given age are more likely to be traded and less likely to be allowed to expire. Second, among patents of the same age, those with higher generality are more likely to be traded and less likely to expire. Third, among traded patents of the same age and especially the recently traded, they are more likely to be retraded and less likely to

by a given year is correlated with the revenue of a patent, the result is consistent with the implications of the theoretical model considered in the paper.

be allowed to expire than the ones not previously traded. Fourth, the number of traded patents as a percentage of all active patents is decreasing with age, but with one exception. The years immediately after a renewal date, this rate discontinuously increases. Finally, the number of patents allowed to expire as a percentage of all active patents increases with age.

These empirical results have implications concerning the way markets for technology are structured and operate. First, the significant number of patents sold and the timing of sale suggest that the patent system permits the transfer of intellectual property assets towards a more profitable use. In theory, a higher value for a given patent might be associated to a better use of the existing technology, complementary assets, or perhaps the improvement of the existing technology that in order to be legally implemented requires the acquisition of prior intellectual property rights. The latter issue is particularly relevant for economic policy because the efficiency of the patent system has been especially criticized in the context in which innovations are sequential and the discovery and adoption of technological improvements might be blocked by incumbents. Second, the fact that small innovators are more likely to sell their patents than their larger counterparts indicates that they might be specializing in research and then sell their patent rights to others, maybe to large firms with a comparative advantage in the production or commercialization process. In this context, understanding the degree of specialization and the size of the gains from trade in the market matters of innovation, mergers and patent policy. For instance, the benefits could offset concerns about the inefficiencies associated to the patent system such the grant of monopoly rights. Third, the model of patent transfer we have used to understand the dynamics of the patent trading suggests that fixed costs of technology adoption explain why patents are more likely to be traded early on during their life cycle as well as the fact that patents with high number of total citations received or high patent generality are more likely to be traded. Finally, the patterns we have presented can provide guidance in the assessment of existing theories and in the development of a new generation of models of intellectual property transfer.

Furthermore, the new data will allow scholars to empirically address questions that previously were not attainable. For instance, Serrano [55], estimates the gains from trade in the market for patents. Other interesting empirical questions in which the data can be useful might be: Do small firms specialize in the creation of knowledge and then sell their patents to their larger counterparts? To estimate the returns to R&D through the market for patents? To what extent does the move towards higher protection of intellectual property rights that occurred in the 1980s facilitate specialization and the transfer of knowledge in the form of patents? Do patent property rights tend to be transferred at the local level like spillovers do? Researchers can also examine policies to promote innovation in the context of markets for technology. For instance, the use of the taxation on the transfer of intellectual property. We leave these topics for future research.

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Appendix

In this section, we discuss the methodology used to create a panel of patents that details their histories of trades and renewal decisions. First, we explain the raw data that we obtained from the USPTO. Second, we present the methodology to identify subsequent assignments, or "reassignments", (i.e., other assignments than the ones from an individual inventor to, generally, the firm that he/she works at). Third, we discuss two caveats of the data. Finally, we describe the sampling of cohorts and the construction of the panel of patents used to derive the main patterns of the transfer of patents.

The Raw Data and the Methodology to Identify Reassignments

The Raw Data

The information obtained from the patent office contains all patent assignments recorded in the USPTO from August 1980 until December of 2001. An assignment as defined by the US Patent Law is a writing document that acknowledges the transfer by a party of all or part of its right, title and interest in a patent or patent application. The data, in principle, includes all patents assigned from inventor to firms, from firms to inventors, from inventor to inventor, and from firm to firm. The total number of patents assigned is very large. There are 2,753,320 records.

Each assignment contains substantial information. In particular, it contains (i) a unique identifier ("Reel Frame"), (ii) the date the assignment was recorded at the USPTO ("Recorded Date"), (iii) the date the private transaction was executed ("Date Signed"), and information on the patents or patent applications that contain such as ("Patent Number", "Application Number", "Issue Date", "Application Date" and "Patent Title"), (iv) the buyer ("Assignee"), (v) the seller ("assignor"). Finally, (vi) a brief comment that summarizes the rational behind the transaction ("Brief").[32]

We separate assignments concerning administrative events using the information contained in the "Brief" field of a patent assignment from the raw data. They are "Assignment of Assignors" (77.66%), "Merger" (3.01%), "Security Interest" (10.08%), "Change of Name" (5.18%), "Nunc Pro Tunc" (0.13%), etc. Later, we will restrict our work to "Assignment of Assignors" and "Merger" (i.e., type 1 and 2). Assignments with brief "Assignment of Assignors" contain both first assignments (i.e., from an inventor to the firm he/she works for) and reassignments (i.e., transactions that potentially represent the transfer of the ownership of a patent across firm boundaries). The rest of the type of assignments (i.e., types 2 to 9) only take place after a first assignment has taken place.[33]

There are few preliminary procedures we do before identifying reassignments. First, we

[32]The information concerning the patents issue date is sometimes missing. We use patent characteristics information related to issue date, application number and date from other sources such as the NBER patent database or the USPTO patent grant data.

[33]There are two minor issues we have dealt with. First, rarely a patent appears more than once in the same assignment. We are treating this as one patent assignments and then eliminate the other recordations. Second, we focus on utility patents.

focus on utility patents. Second, we delete patents assigned more than once within the same assignment. Third, we delete patents eventually withdrawn by the USPTO. Fourth, we consider patents that were granted before January 1, 1975 because are the ones in which both the name of inventors and assignees are available. Finally, we trim commas, dots, slashes, etc. and rename few names of assignees, buyers and sellers.

Identifying reassignments

The main objective is to differentiate first assignments from reassignments. We use of patent characteristics such as the patent's grant date, patent's application date, inventor's name and the name of the owner of the patent by the time the patent is granted (i.e., the "assignee" as of the grant date of the patent).

There are several reasons that makes identifying reassignments difficult. First, an assignment might occur at the application date or at any date thereafter. Consequently, the first assignment of patents granted or applied before August 1980 is not necessarily contained in the raw data on assignments we obtained.[34] Second, we also found (but very rarely) that inventors (only when there is more than one inventor in the patent application) of the same patent might assign it to the same firm using separate assignments. Third, sometimes the same patent is assigned more than once stating same buyer and seller but having different execute and recorded date (this can be as a result of corrections to previous assignments, etc). Fourth, we also found that in some assignments the name of the inventor might differ slightly between the assignment data and the data on granted patents. For instance, the name and last name interchanged. These caveats of the raw data require some explicit methodology.

The methodology we use has two general principles. First, we conjecture that patents that appear to be the first time recorded as an assignment in the raw data are the patents more likely to be considered as "first assignment". However, not all first recordations are first assignments, patents applied before 1980 might appear to be assigned for first time in the raw data but maybe they were already (first) assigned at their application date. Second, we consider that transactions including only one patent with brief of type 1 are more likely to be a first assignment than others. In general, assignments first time recorded that include a single patent should be treated differently in the cleaning process.

First assignments with type 1 brief containing one patent

The number of first assignments with one patent is 1,521,869. The method to identify redundant assignments consists in grouping assignments according to some of its characteristics, and then categorize them in 'types of matches'. We will consider that redundants assignments

[34] In principle all patents with an application date posterior to August 1980 that have been assigned should be included in the raw data. However we have found some (but few) cases that this does not apply for some patents, especially in the last months of the year 1980.

are defined as those with match 1, 2, 4, and the ones that have same application and recorded date.

There are some general rules that we consider when we define what a redundant and a non-redundant assignment is. In particular, redundant assignments are those that would be consistent with first assignments (i.e., an inventor appears as the seller and the buyer is the owner of the patent as of the grant date). Another one is that assignments (other than individual assigned patents) in which the inventor appears as the seller will be considered redundant (i.e., match 4).

(i) Match 1 assignments are those in which the name of the seller coincides with the inventor and the name of buyer coincides with the name of the assignee as of the granted patent date.[35]

(ii) For the rest of assignments, a match 2 assignment is one where the assignee's name coincides with the buyer's name. For instance, this could account for cases in which other inventor than the first one assigns the patent to the assignee (by the grant date).

(iii) For the rest of assignments, a match 3 consists of those assignments where the inventor coincides with the seller, and the type of assignment type is: "not assigned" (i.e., 1), assigned to an "U.S. individual" (i.e., 4), or assigned to a foreign individual (i.e., 5).

(iv) For the rest of the assignments, match 4 are those that the seller coincides with the inventor and the assignee type (as of the grant date) is a "U.S. firm" (i.e., 2), a "foreign firm" (i.e., 3), a "U.S. federal government agency" (i.e., 6) or a "foreign government" (i.e., 7). For instance, in some of these assignments an inventor migh be assigning the patent to the firm he/she work but the name of the assignee might be slightly different from the buyer's name (e.g. buyer as Kabushiki Kaisha Toshiba (or other names) and the assignee is Toshiba Corporation).

(v) Finally, match 5 is left for the rest of assigned patents.

We find that out of all type of assignments the shares are match 1 (83.77%), match 2 (3.19%), match 3 (3.01), match 4 (8.15%) and match 5 (1.88%).

The redundant assignments we consider are the following. First, assignments that are match 1, 2 and 4. Second, assignments that date recorded coincides with the applications date. The rest of the assignments are not redundant. It is not surprising that a larger number of all assignments considering only one patent are redundants (i.e., 95.4%) because first assignments contain only one patent. We have 70,296 non-redundant patent assignments. The conditions for single patent assignments are more restrictive than with the rest of assignments because in principle they are more likely to be redundant.

The rest of assignments

There are 607,057 in this sample. A somewhat modified version of the above rules are applied

[35]First, we eliminate all commas, dots, spaces between of the stream of characters. Then we compare the first four characters. We consider that two streams of characters coincide if the first four characters are exactly the same.

for this sample. The only difference is that assignments under match 4, as defined above, are not considered redundant. We use an alternative method because the assignments in this sample are indeed less likely to represent first assignments (i.e., from inventor to assignee) than the ones in the previous sample. The main reason is simple, inventors assign their patents to the firms they work in a one by one basis, and not in bundles. After the cleaning process, we find that 6.97% of the patent assignments in this sample are redundant, which implies that there are 564,745 non-redundant patent assignments in this sample.

In total, considering first assignments of one patent and the rest of assignment, we have 635,041 non-redundant patent assignments.

Other cleaning issues

We examine four more issues. First, we do not consider transactions in which the buyer and seller are the same entity. In practice, we delete assignments when the first characters of the buyer and seller field coincide only when the patent was originally assigned to corporations or government agencies. The remaining number of patent assignments is 506,510.

Second, we exclude patent assignments in which the word "bank" was contained in either buyer or seller, but only when the word "bank" was initially contained in the name of the assigne of the patent as of its grant date. The reason for this is that we want to minimize the effect of potential labeling mistakes of the USPTO between "Security Interest" and "Assignment of Assignors". The patent assignments left are 490,960.

Third, we exclude patent assignments where the execution date is before the application date. These patents might be as a result of a private contracts either between inventors and firms, or between two firms before the application date of the patent. The remaining number of patent assignments is 464,343.

Fourth, we exclude patent assignments executed when patents were already expired. Sometimes and especially in large bundles of patent assigned, expired patent numbers are included in the records. This leaves us with 453,477 patent assignments.[36]

Finally, out of 453,477, 418,846 are due to "Assignment of Assignors", and 34,631 due to "Merger".

General caveats of the reassignments data

A first caveat is that the USPTO does not distinguish whether patents are traded as a result of an acquisition of a firm or when patents individually acquired. If patents are recorded due to the acquisition of a firm, especially a large firm, then the rational of the transaction can be other than the quality of the patent portfolio of the acquired firm. For instance, the motivation

[36]We conjecture that technologies/innovations are associated pool of patens, thus when a technology is acquired, all patent number associated to that innovation are recorded in a single assignment at the UPSTO. The cost of an assignment are independent of the number of patents included. So, there are little incentives of not recording those patents.

may be expanding market power, etc. To assess the importance of trades associated with firm acquisition, we analyze the time series of patent transfers. In particular, we study the merger waves of mid 1980's and late 1990's. We consider that during acquisition waves firms are less likely to be acquired because of the value of their patent portfolio. According to Mitchell and Mulherin [42], a substantial number of acquisitions in the wave of mid 1980's could be explained by major shocks such as deregulation, increased foreign competition, financial innovations, etc. Next we study how the number of patents contained in a transaction varies at every year in the period 1983-2000. We find that this statistic more than doubles only at years in the mid 1980's and late 1990's. In addition, we also find that the proportion of patents traded in bundles of more than 100 patents disproportionately increases in the same periods. However, the number of patents included in transfers of smaller sizes, such as less than 30 patents, does not increase at the same pace as do their larger counterparts. Therefore, we conclude that patents owned by large innovators are more likely to be recorded for other reasons than their intrinsic technological value than those of small innovators and individual inventors.

A second issue is that the recordation of transfers of patents at the USPTO is not mandatory. We argue that this is a very minor issue. Firms and individuals who buy patents have strong financial incentives to record them at the USPTO because only recorded transfers at the USPTO act as evidence in courts of a bona fide purchase. Moreover, anecdotal evidence from interviews with patent lawyers strongly support the effective recordation of patents traded.

Construction of the data of the transfer of patents

In the panel a period is defined as a year and the age of a patent when traded is the number of years between its trade date and its grant date. For instance, if a patent was traded during its second year of life (e.g. 17 or 22 months since being issued), we consider that the patent was traded at age 2. Similarly, patents can be expired at age 5, 9 or 13 if its renewal fees were not paid at the end of the previous year. For patents applied for prior to June 8, 1995, the term of patent is either 20 years from the earliest claimed filing date or 17 years from the issue date, whichever is longer. For patents applied for after or on June 8, 1995, the maximum lenght is 20 years from the application date.

We consider transfers after a patent's grant date. In practical terms this involves patents that were traded with an execute or signed date higher than their grant date. In principle, U.S. patent law allows for the sales of patent applications, but we have no data prior to 2001 on patent applications of innovations that did not obtain a patent. The lack of the application data does not permit us to calculate the probability that a patent applications is traded. Moreover, it is more likely to fail identifying reassignments among patent assignments signed prior to the grant date of a patent.

The patent level data on the transfer of patents is merged to the number of patent characteristics. In particular, we have patent citations received, the generality measure, technology class, the number of patents granted in a given year for every assignee, etc. We use the NBER patent citations database as the source of the these variables whenever possible, alternatively we can use other sources of patent grant data from the USPTO. In terms of citations, for each patent, we obtain the number of total citations received by every age year. With respect to the generality measure, we consider the generality measure based on the total number of citations over a patent's life, as constructed in the NBER database by Hall, Jaffe and Tratjenberg [24].

Most of the statistics and patterns reported using the data have been constructed by weighting each patent cohort by its number of patents granted or in some cases the number of patents that were not previously expired (i.e., still active). There are positive effects of weighting cohorts and using a large number of patents. In particular, time series effects such as merger waves and economic business cycles are smoothed out through this aggregation.

Finally, the panel we have constructed contains 1,933,470 patents with 198,310 patent assignments, where a patent might have multiple assignments during its life cycle. In particular, there are 170,470 patents traded. Table 4 presents the number of patents granted and the number of patents sold by different types of patentees.

Table 4: Summary Statistics of the Number of Patents Traded and Not Traded over their Life Cycle

	Individually Owned		Corporations			Gov. Agencies
	Unassigned	Priv. Inventors	Small	Medium	Large	
Total	304,087	17,654	453,683	567,081	565,582	25,383
Traded	28,044	2,185	54,533	53,359	31,540	809
Not traded	276,043	15,469	399,150	513,722	534,042	24,574

Table 5: Predicted probability of Patents Traded and Expired by Type of Patentees

Individual owners		Corporations (Innovators)			Govt. Agen.
Unassigned	Priv. Inv.	Small	Medium	Large	
A. Predicted probability of patents traded over their life cycle					
14.1	18.6	18.3	14.1	8.8	4.1
B. Predicted probability of patents expired up to the last renewal fee					
85.0	78.4	61.7	54.0	48.7	89.1

Table 6: Predicted probability of Patents Traded and Expired by Patent Category

Chemical	Computer & Comm	Drugs & Medical	Elec. & Electro.	Mechanical	Other
A. Predicted probability of a patent being traded over the life cycle					
14.4	13.6	13.2	13.4	11.3	11.8
B. Predicted probability of patents expired up to the last renewal fee					
61.3	51.7	58.6	56.5	60.2	63.8

Table 7: Proportion of Patents Traded and Expired by Patent Category and Patentee

	Chemical	Computer & Comm	Drugs & Medical	Elec. & Electro.	Mechanical	Other
A. Proportion of patents traded over their life cycle by patent categories						
Individual owned patents	16.1	15.8	17.0	14.7	11.6	10.1
Unassigned	16.1	15.6	16.8	14.4	11.3	9.9
Priv. Inventor	15.7	19.1	20.1	19.5	16.1	13.7
Corporations (Innovators)	15.0	13.0	16.0	14.0	12.3	14.9
Small	17.2	23.9	20.1	18.2	15.7	16.2
Medium	15.8	16.9	14.2	15.4	12.0	14.1
Large	12.5	7.9	13.3	11.2	8.5	12.3
Govt. Agencies	4.0	2.6	4.4	4.6	4.7	3.2
All	14.9	12.9	16.0	13.8	12.0	13.1
B. Proportion of patents expired up to the last renewal fee by patent categories						
Individual owned patents	77.5	73.0	69.3	68.4	74.1	81.1
Unassigned	72.8	69.8	69.0	74.6	79.3	81.3
Priv. Inventor	75.6	62.3	60.1	66.3	77.0	77.1
Corporations (Innovators)	58.3	44.6	54.5	51.9	56.7	60.1
Small	59.0	54.2	53.2	58.7	62.4	63.9
Medium	58.5	46.6	54.1	52.5	57.2	57.3
Large	57.6	40.6	59.1	48.1	49.0	53.6
Govt. Agencies	80.7	91.6	65.1	84.3	86.5	86.8
All	60.0	47.3	57.4	55.1	61.7	67.9

Table 8: Estimates of the Logit Regressions of the Decision to Trade or Allow a Patent to Expire Conditional on the Number of Patent Citations Received

	All	Individually Owned			Corporations (Innovators)				Govt. agen.
		All	Unassigned	Priv. inv.	All	Small	Medium	Large	
A. Trading Decision									
With age dummies									
total_citations	0.00689	0.0192	0.0192	0.00185	0.00498	0.0132	0.00562	-0.00614	0.00306
	(0.000295)	(0.000672)	(0.0007)	(0.00245)	(0.000309)	(0.000445)	(0.0005521)	(0.000934)	(0.0063)
With age and patent category dummies									
total_citations	0.00703	0.0163	0.0162	0.0174	0.00537	0.0109	0.00491	-0.00250	0.00432
	(0.000297)	(0.000683)	(0.000710)	(0.00254)	(0.000311)	(0.000463)	(0.000527)	(0.000910)	(0.00603)
With age, patent category and patentee dummies									
total_citations	0.00744	-	-	-	-	-	-	-	-
	(0.00029)	-	-	-	-	-	-	-	-
Obs	12876456	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070
B. Expiration Decision									
With age dummies									
total_citations	-0.0579	-0.0450	-0.0448	-0.0445	-0.0557	-0.0478	-0.0594	-0.0527	-0.0518
	(0.000346)	(0.000820)	(0.000848)	(0.00318)	(0.000385)	(0.000677)	(0.000663)	(0.0006531)	(0.00265)
With age and patent category dummies									
total_citations	-0.0532	-0.0406	-0.0406	-0.0394	-0.0522	-0.0834	-0.0572	-0.0480	-0.0529
	(0.000350)	(0.000835)	(0.000864)	(0.00324)	(0.000388)	(0.00866)	(0.000667)	(0.000654)	(0.00271)
With age, patent category and patentee dummies									
total_citations	-0.0499	-	-	-	-	-	-	-	-
	(0.000349)	-	-	-	-	-	-	-	-
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level.

Table 9: Estimates of the Logit Regressions of the Decision to Trade and Expire a Patent for Previously Traded Patents

	All	Individual Owners			Corporations (Innovators)				Govt. agen.
		All	Unassigned	Priv. inv.	All	Small	Medium	Large	
A. Trading Decision									
Controls: age dummies									
Previouslytraded	1.0401	1.1221	1.1376	0.8926	1.0085	0.8591	0.8904	1.1814	0.9091
	(0.00691)	(0.0156)	(0.0162)	(0.0570)	(0.00774)	(0.0116)	(0.0130)	(0.0177)	(0.1530)
Controls: age and patent category dummies									
Previouslytraded	1.0317	1.0926	1.1052	0.8894	0.9976	0.8425	0.8793	1.1451	0.8631
	(0.00692)	(0.0156)	(0.0163)	(0.0570)	(0.00775)	(0.0116)	(0.0130)	(0.0178)	(0.1533)
Controls: age, patent category dummies and citations									
Previouslytraded	1.0277	1.0716	1.0844	0.8684	0.9952	0.8307	0.8776	1.1447	0.8588
	(0.00692)	(0.0157)	(0.0163)	(0.0572)	(0.00776)	(0.0117)	(0.013)	(0.0178)	(0.1537)
Controls: age, patent category, patentee dummies and citations									
Previouslytraded	0.9428	-	-	-	-	-	-	-	-
	(0.00697)	-	-	-	-	-	-	-	-
Obs	10942986	1647334	1551961	95373	9145965	2610335	3381661	3153969	149687
B. Expiration Decision									
Controls: age dummies									
Previouslytraded	-0.3011	-0.8969	-0.8993	-0.8264	-0.1552	-0.3440	-0.1136	-0.1379	-1.0576
	(0.00573)	(0.0128)	(0.0132)	(0.0490)	(0.00647)	(0.0101)	(0.0103)	(0.0148)	(0.0746)
Controls: age and patent category dummies									
Previouslytraded	-0.3155	-0.8723	-0.8730	-0.8355	-0.1663	-0.3341	-0.1060	-0.1762	-1.0472
	(0.00576)	(0.0128)	(0.0133)	(0.0492)	(0.00649)	(0.0102)	(0.0104)	(0.0148)	(0.0751)
Controls: age, patent category dummies and citations									
Previouslytraded	-0.2904	0.8270	-0.8280	-0.7882	-0.1482	-0.2906	-0.0910	-0.1913	-0.9873
	(0.0058)	(0.0129)	(0.0134)	(0.0495)	(0.00654)	(0.0102)	(0.0104)	(0.0150)	(0.0759)
Controls: age, patent category, patentee dummies and citations									
Previouslytraded	-0.3554	-	-	-	-	-	-	-	-
	(0.00589)	-	-	-	-	-	-	-	-
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level.

Table 10: Estimates of the Logit Regressions of the Decision to Allow a Patent to Expire or Being Traded Conditional on Patent Generality

	All	Individually owned			Corporations (Innovators)				Govt. agen.
		All	Unassigned	Priv. inv.	All	Small	Medium	Large	
A. Trading Decision									
With age dummies									
generality	0.1902	0.2144	0.2127	0.2132	0.1978	0.2011	0.1833	0.2099	-0.0860***
	(0.00697)	(0.0160)	(0.0166)	(0.0591)	(0.00777)	(0.0121)	(0.0126)	(0.0169)	(0.1020)
With age and patent category dummies									
generality	0.2119	0.2109	0.2092	0.2051	0.2146	0.1975	0.1749	0.2125	-0.0928***
	(0.00699)	(0.0162)	(0.0168)	(0.0602)	(0.00779)	(0.0122)	(0.0127)	(0.0169)	(0.1020)
With age, patent category dummies and citations									
generality	0.2073	0.2034	0.2015	0.1997	0.2109	0.1903	0.1710	0.2151	-0.0978***
	(0.00702)	(0.0163)	(0.0169)	(0.0606)	(0.00781)	(0.0123)	(0.0127)	(0.0169)	(0.1025)
With age, patent category, patentee dummies and citations									
generality	0.1977	-	-	-	-	-	-	-	-
	(0.00703)	-	-	-	-	-	-	-	-
Obs	12876456	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070
Used	11395526	1717383	1617743	99640	9527208	2707508	3485280	3334430	150170
B. Expiration Decision									
With age dummies									
generality	-0.1862	-0.0982	-0.0965	-0.1056*	-0.1765	-0.1418	-0.2099	-0.1828	-0.1145
	(0.00508)	(0.0106)	(0.0109)	(0.0459)	(0.00596)	(0.0101)	(0.00978)	(0.0114)	(0.0350)
With age and patent category dummies									
generality	-0.1681	-0.0958	-0.0940	-0.1110	-0.1666	-0.1407	-0.2012	-0.1670	-0.1224
	(0.00510)	(0.0108)	(0.0111)	(0.0465)	(0.00597)	(0.0101)	(0.00980)	(0.0114)	(0.0352)
With age, patent category dummies and citations									
generality	-0.0502	-0.0386	-0.0386	-0.0369	-0.0492	-0.0435	-0.0538	-0.0455	-0.0511
	(0.000359)	(0.000856)	(0.000887)	(0.0033)	(0.000399)	(0.000707)	(0.000687)	(0.000671)	(0.0281)
With age, patent category, patentee dummies and citations									
generality	-0.0818	-	-	-	-	-	-	-	-
	(0.00513)	-	-	-	-	-	-	-	-
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882
Used	2084493	331408	312327	19081	1721853	501791	637128	582934	31232

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level.

Table 11: Estimates of the Logit Regressions of the Decision to Trade and let a Patent Expire Conditioning on the Number of Years Since the Last Transfer

	All	Individual Owners			Corporations (Innovators)				Govt. agen.
		All	Unassigned	Priv. inv.	All	Small	Medium	Large	
A. Trading decision									
With age dummies									
tradedyearsago	-0.1236	-0.1932	-0.2013	-0.0819***	-0.1092	-0.0968	-0.1642	-0.0274***	0.5787*
	(0.00815)	(0.0177)	(0.0183)	(0.0714)	(0.00919)	(0.0136)	(0.0150)	(0.0232)	(0.2831)
tradedyearsago^2	0.00548	0.00938	0.00999	0.000386***	0.00466	0.00457	0.0102	-0.00825	-0.0729*
	(0.000725)	(0.00156)	(0.00160)	(0.00681)	(0.000819)	(0.00123)	(0.00128)	(0.00227)	(0.0294)
With age and patent category dummies									
tradedyearsago1	-0.1235	-0.1929	-0.2014	0.0788***	-0.1091	-0.0964	-0.1639	-0.028***	0.5869*
	(0.00815)	(0.0177)	(0.0183)	(0.0715)	(0.00919)	(0.0136)	(0.0150)	(0.0232)	(0.2830)
tradedyearsago^2	0.00547	0.00939	0.0100	0.000421***	0.00463	0.00461	0.0101	-0.00795	-0.0728*
	(0.000725)	(0.00156)	(0.00160)	(0.00681)	(0.000819)	(0.00123)	(0.00128)	(0.00226)	(0.0293)
With age, patent category dummies and citations									
tradedyearsago1	-0.1234	-0.1934	-0.2018	-0.0798***	-0.1089	-0.0962	-0.1635	-0.028***	0.5849*
	(0.00815)	(0.0177)	(0.0183)	(0.0715)	(0.00919)	(0.0136)	(0.015)	(0.0232)	(0.2839)
tradedyearsago^2	0.0055	0.00949	0.0101	0.000652***	0.00466	0.00461	0.0101	-0.00789	-0.0729*
	(0.000725)	(0.00156)	(0.0016)	(0.00682)	(0.000819)	(0.00123)	(0.00128)	(0.00226)	(0.0293)
With age, patent category, patentee dummies and citations									
tradedyearsago1	-0.1291	-	-	-	-	-	-	-	-
	(0.00815)	-	-	-	-	-	-	-	-
tradedyearsago^2	0.00582	-	-	-	-	-	-	-	-
	(0.000724)	-	-	-	-	-	-	-	-
Obs	10942986	1647334	1551961	95373	9145965	2610335	3381661	3153969	149687
Used	833270	156274	144592	11682	672783	271308	260889	140586	4213
B. Expiration decision									
With age dummies									
tradedyearsago	0.3699	0.4013	0.4099	0.2959	0.3589	0.3166	0.3565	0.4271	0.4828
	(0.0080)	(0.0188)	(0.0196)	(0.0693)	(0.00890)	(0.0138)	(0.0143)	(0.0202)	(0.1123)
tradedyearsago^2	-0.0225	-0.0230	-0.0236	-0.0149	-0.0222	-0.0201	-0.0210	-0.0278	-0.0364
	(0.000643)	(0.00148)	(0.00154)	(0.00534)	(0.000720)	(0.00113)	(0.00114)	(0.00164)	(0.00939)
With age and patent category dummies									
tradedyearsago	0.370	0.4047	0.4141	0.2999	0.3594	0.3192	0.3565	0.4298	0.4984
	(0.00802)	(0.0189)	(0.0196)	(0.0694)	(0.00892)	(0.0139)	(0.0143)	(0.0202)	(0.1130)
tradedyearsago^2	-0.0226	-0.0231	-0.0237	-0.0151	-0.0223	-0.0204	-0.0210	-0.0279	-0.0374*
	(0.000645)	(0.00148)	(0.00155)	(0.00535)	(0.000721)	(0.00113)	(0.00114)	(0.00165)	(0.00945)
With age, patent category dummies and citations									
tradedyearsago	0.3691	0.4080	0.4172	0.3087	0.3574	0.3193	0.3498	0.4309	0.5085
	(0.00807)	(0.0190)	(0.0197)	(0.0701)	(0.00897)	(0.0139)	(0.0144)	(0.0204)	(0.1143)
tradedyearsago^2	-0.0226	-0.0232	-0.0239	-0.0154	-0.0223	-0.0204	-0.0207	-0.0285	-0.0362
	(0.00065)	(0.00149)	(0.00156)	(0.0054)	(0.000727)	(0.00114)	(0.00115)	(0.00167)	(0.00959)
With age, patent category, patentee dummies and citations									
tradedyearsago	0.3641	-	-	-	-	-	-	-	-
	(0.00807)	-	-	-	-	-	-	-	-
tradedyearsago^2	-0.0225	-	-	-	-	-	-	-	-
	(0.00065)	-	-	-	-	-	-	-	-
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882
Used	212705	39844	36906	2938	171754	69986	66495	35273	1107

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, ***Not statistically significant at the 10% level, and ****The valididty of the model fit is questinable.

Table 12: Estimates of the Logit Regressions of the Decision to Sell and Expire a Patent Conditional on its Age by Type of Patentees (With Age Dummies)

	All	Individually Owned			Corporations (Innovators)				Govt. agen****
		All	Unassigned	Priv. inv.****	All	Small	Medium	Large	
A. Trading decision with age dummies									
intercept	-4.8354	-4.7893	-4.7185	-	-4.8341)	-4.7686	-4.6403	-5.170	-
	(0.0448)	(0.1392)	(0.1393)	-	(0.0473	(0.0894)	(0.0692)	(0.0943)	-
age_year1	0.8306	1.2407	1.1498	-	0.7586	1.1072)	0.6722	-0.3664	-
	(0.0451)	(0.1396)	(0.1397)	-	(0.0477)	(0.00899	(0.0692)	(0.0955)	-
age_year2	0.7499	0.8487	0.7586	-	0.7281	1.0352	0.6248	0.4421	-
	(0.0451)	(0.1399)	(0.1400)	-	(0.0478)	(0.090)	(0.070)	(0.0955)	-
age_year3	0.6861	0.6726	0.5869	-	0.6915	0.9748	0.5513	0.5043	-
	(0.0452)	(0.1400)	(0.1402)	-	(0.0478)	(0.0901)	(0.0710)	(0.0956)	-
age_year4	0.6807	0.6586	0.5685	-	0.6869	0.9644	0.5173	0.5443	-
	(0.0453)	(0.1401)	(0.1403)	-	(0.0479)	(0.0902)	(0.0702)	(0.0957)	-
age_year5	0.7119	0.8275	0.7376	-	0.6934	0.9835	0.4826	0.6330	-
	(0.0454)	(0.1405)	(0.1406)	-	(0.0481)	(0.0904)	(0.0706)	(0.0957)	-
age_year6	0.5990	0.6301	0.5455	-	0.5937	0.8854	0.3877	0.5172	-
	(0.0456)	(0.1409)	(0.1411)	-	(0.0482)	(0.0906)	(0.0708)	(0.0963)	-
age_year7	0.5559	0.5490	0.4615	-	0.5613	0.8259	0.3311	0.5593	-
	(0.0457)	(0.1412)	(0.1414)	-	(0.0484)	(0.0908)	(0.0711)	(0.0964)	-
age_year8	0.5446	0.5972	0.5132	-	0.5412	0.8163	0.2659	0.5834	-
	(0.0458)	(0.1413)	(0.1415)	-	(0.0485)	(0.0910)	(0.0711)	(0.0966)	-
age_year9	0.6311	0.7974	0.7124	-	0.6039	0.8441	0.3283	0.7258	-
	(0.0462)	(0.1425)	(0.1428)	-	(0.0490)	(0.0918)	(0.0724)	(0.0972)	-
age_year10	0.5971	0.6849	0.5949	-	0.5837	0.7573	0.4074	0.6565	-
	(0.0465)	(0.1432)	(0.1436)	-	(0.0492)	(0.0923)	(0.0725)	(0.0979)	-
age_year11	0.5500	0.6849	0.5515	-	0.5331	0.6968	0.3173	0.6565	-
	(0.0468)	(0.1432)	(0.1445)	-	(0.0496)	(0.0929)	(0.0733)	(0.0979)	-
age_year12	0.4789	0.5853	0.5190	-	0.4607	0.6097	0.2553	0.6008	-
	(0.0473)	(0.1451)	(0.1455)	-	(0.0501)	(0.0938)	(0.0743)	(0.0993)	-
age_year13	0.5954	0.8155)	0.7331	-	0.5627	0.6960	0.4627	0.5816	-
	(0.0487)	(0.1488	(0.1496)	-	(0.0517)	(0.0965)	(0.0763)	(0.1028)	-
age_year14	0.5378	0.6785	0.6197	-	0.5172	0.6994	0.2806)	0.6638	-
	(0.0500)	(0.1529)	(0.1537)	-	(0.0530)	(0.0982)	(0.0796	(0.1042)	-
age_year15	0.3606	0.5766	0.4955	-	0.3270)	0.4864	0.1981*	0.3550	-
	(0.0523)	(0.1578)	(0.1593)	-	(0.0556	(0.1027)	(0.0830)	(0.1104)	-
age_year16	0.3114	0.2433)	0.1992***	-	0.3141	0.3213	0.1552**	0.5464	-
	(0.0552)	(0.1729	(0.1743)	-	(0.0584)	(0.1098)	(0.0878)	(0.1125)	-
Obs	12876456	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070
B. Expiring decision with age dummies									
intercept	-0.6941	-0.2969	-0.2900	-0.4012	-0.7631	-0.7075	-0.7265	-0.8504	0.0895*
	(0.00395)	(0.0108)	(0.0112)	(0.0437)	(0.00429)	(0.00811)	(0.00690)	(0.00744)	(0.0368)
age_year5	-0.8806	-0.3888	-0.3809	-0.5512	-1.1018	-0.7820	-1.1864	-1.4035	-1.2133
	(0.00458)	(0.0117)	(0.0121)	(0.0479)	(0.00515)	(0.00931)	(0.00840)	(0.00942)	(0.0402)
age_year9	-0.2293	-0.0126	-0.0126	-0.0185***	-0.3133	-0.1809	-0.3417	-0.4122	0.1703
	(0.0202)	(0.0125)	(0.0129)	(0.0506)	(0.00521)	(0.00967)	(0.00840)	(0.00917)	(0.0412)
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, *** Not statistically significant at the 10% level, ****The valididty of the model fit is questinable.

Table 13: Estimates of the Logit Regressions of the Decision to Sell and Expire a Patent Conditional on its Age by Type of Patentees (With Age and Patent Category Dummies)

	All	Individually Owned			Corporations (Innovators)				Govt. age.****
		All	Unassigned	Priv. inv.****	All	Small	Medium	Large	
A. Trading decision with age and patent category dummies									
intercept	-4.7716	-4.9988	-4.9320	-	-4.7036	-4.8248	-4.6152	-4.9348	-
	(0.0450)	(0.1395)	(0.1395)	-	(0.0476)	(0.0897)	(0.0698)	(0.0958)	-
age_year1	0.8584	1.2533	1.635	-	0.7617	1.0819	0.6687	0.3968	-
	(0.0451)	(0.1397)	(0.1397)	-	(0.0477)	(0.0899)	(0.0699)	(0.0955)	-
age_year2	0.7475)	0.8623	0.7733	-	0.7305	1.0121	0.6219	0.4689	-
	(0.0452	(0.1399)	(0.1400)	-	(0.0478)	(0.0900)	(0.0700)	(0.0956)	-
age_year3	0.6835	0.6869	0.6024	-	0.6932	0.9541	0.5490	0.5276	-
	(0.0452)	(0.1401)	(0.1402)	-	(0.0479)	(0.0901)	(0.0701)	(0.0956)	-
age_year4	0.6780	0.6743	0.5853	-	0.6883	0.9461	0.5157	0.5640	-
	(0.0453)	(0.1401)	(0.1403)	-	(0.0479)	(0.0902)	(0.0702)	(0.0957)	-
age_year5	0.7110	0.8324	0.7432	-	0.6964	0.9655	0.4808	0.6529	-
	(0.0454)	(0.1405)	(0.1407)	-	(0.0481)	(0.0904)	(0.0706)	(0.0959)	-
age_year6	0.5986)	0.6365	0.5527	-	0.5967	0.8694	0.3866	0.5342	-
	(0.0456	(0.1409)	(0.1411)	-	(0.0482)	(0.0906)	(0.0709)	(0.0963)	-
age_year7	0.5554	0.5572	0.4704	-	0.5640	0.8118	0.3309	0.5726	-
	(0.0457)	(0.1412)	(0.1414)	-	(0.0484)	(0.0908)	(0.0711)	(0.0965)	-
age_year8	0.5443	0.6073	0.5240	-	0.5437	0.8038	0.2667	0.5939	-
	(0.0458)	(0.1413)	(0.1415)	-	(0.0485)	(0.0910)	(0.0715)	(0.0966)	-
age_year9	0.6326	0.7953	0.7104	-	0.6085	0.8299	0.3280	0.7427	-
	(0.0462)	(0.1425)	(0.1428)	-	(0.0490)	(0.0918)	(0.0724)	(0.0972)	-
age_year10	0.5988	0.6839	0.5940	-	0.5882	0.7445	0.4077	0.6719	-
	(0.0465)	(0.1433)	(0.1437)	-	(0.0492)	(0.0923)	(0.0725)	(0.0979)	-
age_year11	0.5517	0.6507	0.5530	-	0.5373	0.6851	0.3174	0.6833	-
	(0.0468)	(0.1440)	(0.1445)	-	(0.0496)	(0.0929)	(0.0733)	(0.0984)	-
age_year12	0.4808	0.5872	0.5214	-	0.4646	0.5993	0.2551	0.6132	-
	(0.0473)	(0.1451)	(0.1455)	-	(0.0502)	(0.0939)	(0.0743)	(0.0993)	-
age_year13	0.5983	0.8100	0.7280	-	0.5679	0.6845	0.4620	0.6003	-
	(0.0487)	(0.1489)	(0.1497)	-	(0.0517)	(0.0965)	(0.0763)	(0.1028)	-
age_year14	0.5408	0.6749	0.6166	-	0.5220	0.6916	0.2805	0.6811	-
	(0.0500)	(0.1529)	(0.1538)	-	(0.0530)	(0.0982)	(0.0796)	(0.1042)	-
age_year15	0.3629	0.5742	0.4934	-	0.3306	0.4812	0.1986*	0.3688	-
	(0.0523)	(0.1578)	(0.1593)	-	(0.0556)	(0.1027)	(0.0830)	(0.1104)	-
age_year16	0.3123	0.2423***	0.1982***	-	0.3156	0.3192	0.1556**	0.5532	-
	(0.0552)	(0.1730)	(0.1743)	-	(0.0584)	(0.1098)	(0.0878)	(0.1125)	-
Obs	12876456	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070
B. Expiring decision with age and patent category dummies									
intercept	-0.3483	-0.1314	-0.1270	-0.2172	-0.5601	-0.5771	-0.6523	-0.7339	0.2372
	(0.00495)	(0.0117)	(0.0121)	(0.0484)	(0.00582)	(0.00954)	(0.00961)	(0.0140)	(0.0506)
age_year5	-0.8935	-0.4045	-0.3964	-0.5712	-1.1014	-0.7795	-1.1854	-1.4110	-1.2431
	(0.00461)	(0.0118)	(0.0121)	(0.0482)	(0.00517)	(0.00933)	(0.00841)	(0.00948)	(0.0405)
age_year9	-0.2366	-0.0199***	-0.0198***	-0.0305***	-0.3157	-0.1802	-0.3428	-0.4216	0.1537
	(0.00476)	(0.0125)	(0.0129)	(0.0509)	(0.00522)	(0.00969)	(0.00842)	(0.00922)	(0.0415)
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, *** Not statistically significant at the 10% level, ****The valididty of the model fit is questionable.

Table 14: Estimates of the Logit Regressions of the Decision to Sell and Expire a Patent Conditional on its Age by Type of Patentees (With Age, Patent Category Dummies and Citations)

	All	Individually Owned			Corporations (Innovators)				Govt. agen.
		All	Unassigned	Priv. inv.****	All	Small	Medium	Large	
A. Trading decision with age,patent category dummies and citations									
intercept	-4.8493	-5.2216	-5.1547	-	-4.7020	-4.9452	-4.6651	-4.9087	-6.4821
	(0.0452)	(0.1419)	(0.1421)		(0.0478)	(0.0899)	(0.070)	(0.0963)	(1.0095)
age_year1	0.9408	1.4837	1.3937	-	0.8238)	1.2103	0.7211	0.3698	1.1199***
	(0.0453)	(0.1422)	(0.1424)		(0.0479	(0.0901)	(0.0701)	(0.0960)	(1.00620)
age_year2	0.8258	1.0857	0.9966	-	0.7893	1.1347	0.6713	0.4436	0.9398***
	(0.0454)	(0.1424)	(0.1426)		(0.0480)	(0.0902)	(0.0702)	(0.0960)	(1.0069)
age_year3	0.7561	0.9001	0.8155	-	0.7474)	1.0681	0.5945	0.5047	0.6874***
	(0.0454)	(0.1425)	(0.1427)		(0.0480	(0.0903)	(0.0703)	(0.0960)	(1.0081)
age_year4	0.7444	0.8757	0.7867	-	0.7377	1.0504	0.5568	0.5436	0.9645***
	(0.0454)	(0.1425)	(0.1428)		(0.0481)	(0.0903)	(0.0704)	(0.0960)	(1.0067)
age_year5	0.7700	1.0185	0.9295	-	0.7400	1.0581	0.5168	0.6352	0.8431***
	(0.0456)	(0.1428)	(0.1431)		(0.0482)	(0.0905)	(0.0707)	(0.0961)	(1.0090)
age_year6	0.6512	0.8086	0.7253	-	0.6354	0.9515	0.4183	0.5188	1.2338***
	(0.0457)	(0.1432)	(0.1435)		(0.0483)	(0.0907)	(0.0709)	(0.0965)	(1.0068)
age_year7	0.6027	0.7172	0.6312	-	0.5985	0.8844	0.3590	0.5592)	0.6795***
	(0.0458)	(0.1434)	(0.1437)		(0.0484)	(0.0909)	(0.0712)	(0.0966	(1.0108)
age_year8	0.5866	0.7552	0.6727	-	0.5744	0.8675	0.2917	0.5821	0.2795***
	(0.0459)	(0.1435)	(0.1438)		(0.0486)	(0.0910)	(0.0715)	(0.0967)	(1.0160)
age_year9	0.6661	0.9179	0.8340	-	0.6329	0.8786	0.3474	0.7335	1.2004***
	(0.0463)	(0.1446)	(0.1450)		(0.0490)	(0.0918)	(0.0724)	(0.0973)	(1.0157)
age_year10	0.6279	0.7943	0.7054	-	0.6094	0.7855	0.4244	0.6640	0.8873***
	(0.0466)	(0.1453)	(0.1458)		(0.0493)	(0.0923)	(0.0725)	(0.0979)	(1.0235)
age_year11	0.5770	0.7511	0.6547	-	0.5557	0.7184	0.3319	0.6766	1.1492***
	(0.0469)	(0.1460)	(0.1466)		(0.0497)	(0.0929)	(0.0733)	(0.0984)	(1.0207)
age_year12	0.5022	0.6759	0.6120	-	0.4803	0.6262	0.2671	0.6076	1.1230***
	(0.0474)	(0.1471)	(0.1476)		(0.0502)	(0.0939)	(0.0743)	(0.0994)	(1.0244)
age_year13	0.6086	0.8632	0.7843	-	0.5754	0.6914	0.4672	0.5978	1.1614***
	(0.0488)	(0.1508)	(0.1517)		(0.0517)	(0.0965)	(0.0763)	(0.1028)	(1.0550)
age_year14	0.5471	0.7140	0.6591	-	0.5264	0.6902	0.2834	0.6794	1.1184***
	(0.0501)	(0.1549)	(0.1558)		(0.0530)	(0.0982)	(0.0796)	(0.1042)	(1.0700)
age_year15	0.3671	0.6025	0.5250	-	0.3336	0.4789	0.1987*	0.3679	1.3161***
	(0.0524)	(0.1598)	(0.1613)		(0.0557)	(0.1028)	(0.0830)	(0.1104)	(1.0701)
age_year16	0.3160	0.2544***	0.2131***	-	0.3185	0.3185	0.1568**	0.5525	1.4790***
	(0.0553)	(0.1750)	(0.1765)		(0.0584)	(0.1098)	(0.0879)	(0.1125)	(1.0813)
Obs	12876456	1969075	1856048	113027	10732311	3064018	3948742	3719551	175070
B. Expiring decision with age, patent category dummies and citations									
intercept	0.00883***	0.1336	0.1364	0.0629***	-0.2035	-0.2603	-0.2722	-0.3745	0.5870
	(0.00545)	(0.0129)	(0.0133)	(0.0533)	(0.00636)	(0.0105)	(0.0105)	(0.0148)	(0.0540)
age_year5	-1.1390	-0.5939	-0.0406	-0.7755	-1.3425	-1.0015	-1.4353	-1.6417	-1.5186
	(0.00488)	(0.0124)	(0.000864)	(0.0510)	(0.00546)	(0.00993)	(0.00862)	(0.00941)	(0.0433)
age_year9	-0.3490	-0.1113	-0.1103	-0.1316	-0.4247	-0.2821	-0.4576	-0.5228	0.0136
	(0.00487)	(0.0128)	(0.0132)	(0.0520)	(0.00534)	(0.00988)	(0.00862)	(0.00941)	(0.0427)
Obs	2321364	373918	352559	21359	1911564	559918	712799	638847	35882

*Not statiscally significant at the 1% level, **Not statistically significant at the 5% level, *** Not statistically significant at the 10% level, ****The valididty of the model fit is questinable.

Table 15: Estimates of the Logit Regressions of the Decision to Sell and Expire Patent Conditional on its Age by Type of Patentees (With Age, Patent Category, Patentee Dummies and Citations)

A. Trading decision with age, patent category, patentee dummies and citations	
intercept	-6.1570
	(0.0568)
age_year1	0.9253
	(0.0453)
age_year2	0.8082
	(0.0454)
age_year3	0.7363
	(0.0454)
age_year4	0.7222
	(0.0455)
age_year5	0.7576
	(0.0456)
age_year6	0.6380
	(0.0457)
age_year7	0.5885
	(0.0458)
age_year8	0.5724
	(0.0459)
age_year9	0.6584
	(0.0463)
age_year10	0.6186
	(0.0466)
age_year11	0.5663
	(0.0469)
age_year12	0.4915
	(0.0474)
age_year13	0.6021
	(0.0488)
age_year14	0.5389
	(0.0501)
age_year15	0.3619
	(0.0524)
age_year16	0.3112
	(0.0553)
obs	12876456

B. Expiring decision with age, patent category, patentee dummies and citations	
intercept	0.6308
	(0.0126)
age_year5	-1.2198
	(0.00497)
age_year9	-0.3853
	(0.00493)
Obs	2321364