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# Patent Characteristics and Patent Ownership Change in Agricultural Biotechnology

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We examine the effect of various patent characteristics on changes in patent ownership that occurred due to mergers, acquisitions, and spin-offs in the agricultural biotechnology industry in the 1980s and 1990s. Our goal is to shed light on the role that certain patent qualities may play in the transfer of knowledge and technology that takes place through merger and acquisition activity. Specifically, we empirically measure the effect of patent value, scope/breadth, strength, and the nationality of the patent owner on the occurrence and frequency of patent ownership change in the agricultural biotechnology sector during the 1980s and 1990s. We find that the greater is the patent breadth and the less valuable and 'weaker' is the patent, the greater is the likelihood and the frequency of patent ownership change. Also, the nature of patent ownership affects patent ownership change, with patents owned by multiple owners of different nationalities most likely to change hands.

***Key words:*** patent characteristics, patent ownership change, patent value, patent breadth, patent strength, agricultural biotechnology, mergers and acquisitions.

## Introduction

Patents are often viewed as the strongest form of intellectual property protection.[1] The rationale for granting patents is to stimulate innovative activity through the disclosure of technical information and to encourage investment in innovation through a temporary monopoly that prevents others from commercially benefiting from the innovator's research. Patents have promoted new technologies and boosted the development of many industries through the provision of much-needed incentives for innovation. A case in point is biotechnology in general—and agricultural biotechnology in particular—which experienced tremendous growth following the Diamond vs. Chakrabarty Supreme Court ruling in 1980 that allowed the patenting of living organisms.

Starting in the mid-1980s and up until the early-2000s, the number of biotechnology (including agricultural biotechnology) patent applications to, and patents granted by, the United States Patent and Trademark Office (USPTO) grew exponentially (Adelman & DeAngelis, 2007; Graff, Rausser, & Small, 2003). The rapid growth in biotechnology patenting led to claims that it would impede innovation, thus leading to anti-commons problems. Empirical studies—including a comprehensive study by Adelman and DeAngelis (2007) that examined more than 52,000 biotechnology patents issued by the USPTO during the period 1990-2004—provide no support for the anti-commons theory in biotechnology. Adelman and DeAngelis (2007) showed that biotechnology patent applications kept increasing in the mid-2000s even though the number of patents granted by the USPTO started falling due to the introduction of more stringent standards, new entrants continued entering in the biotechnology sector, and ownership of biotechnology patents was diffuse with the number of entities obtaining biotechnology patents continuously increasing during their study period.

During this period of growth for biotechnology patents, the agricultural biotechnology industry experienced consolidation and restructuring. Joint ventures, contracts, licensing arrangements, mergers, acquisitions, and strategic alliances increased and led to greater cooperation among firms.[2] There is little dispute that a firm's intellectual property plays an important role in changes in its ownership structure. This is especially true when this intellectual property is protected by a patent (as opposed to being kept a trade secret), in which case all relevant knowledge has to be disclosed, thus making it

1. *A patent provides its owner exclusive rights over a claimed invention and is granted by the Patent Office of a country or group of countries (e.g., the European Patent Office) on the basis of a patent application. The exclusive right provides a legal right to the patent owner to exclude others from making, using, offering for sale, selling, or importing the patented invention without the owner's permission for a period of up to 20 years from the date that the application for patent was filed. In return, the owner is required to disclose the claimed invention to the public.*

easier (for competitors and/or complementors) to evaluate its scope and value.[3] Schimmelpfennig, King, and Naseem (2003) showed that the acquisition of intellectual property is an important motivator for mergers and acquisitions and as significant as physical capital, while Graff et al. (2003) found that firms tend to acquire complementary intellectual property. Rausser (1999) drew attention to the fact that a major motivation behind the mergers and acquisitions in the agricultural biotechnology industry in the 1980s and 1990s was, according to industry insiders, control over patent rights. To investigate this claim, Marco and Rausser (2008) empirically examined the role patent rights played in the consolidation of the agricultural biotechnology industry, using patents as explanatory variables for mergers, acquisitions, and spin-offs. Specifically, the study examined how patent enforceability, which was captured by various patent characteristics, affects the likelihood of consolidation and found that it is an important factor and that firms that hold strongly-protected patents are more likely to engage in acquisitions than firms that hold weakly-protected patents.

Not all patents are equally attractive, however, to firms that could potentially desire to control the technology and knowledge that they protect. The commercial and strategic value of a patent depends not only on the nature of the innovation the patent protects but, critically, on patent characteristics such as the scope/breadth of the patent that, to a large extent, determine the patent's legal strength (e.g., the extent to which a patent can survive a validity challenge) and consequently the effective life of the patent.[4] As an example, a broad patent makes it harder for competitors to enter the market with non-infringing innovations, which may increase the incentive to acquire the firm that holds them. At the same time, a broad patent is more likely to be legally challenged and infringed and less likely to survive a direct or indirect validity challenge; these factors affect the value the patent confers to its owner (Yiannaka & Fulton, 2006) and may influence their decision to transfer ownership.

Given that in addition to patents and other intellectual property rights, complex financial and (often unobservable) strategic factors influence a firm's decision to merge or acquire, we cannot directly measure the effect of patent characteristics on a firm's incentive to merge or acquire. In this study, we try to gain insights on the role certain patent qualities may play in the transfer of knowledge and technology that takes place through mergers and acquisitions by examining what type of patents were more likely to change hands in the agricultural biotechnology industry in the 1980s and 1990s when the change of ownership was the result of mergers, acquisitions, and spin-offs.

Specifically, using a dataset of 6,223 private-sector agricultural biotechnology patents issued between 1976 and 2000 by the USPTO, we investigate whether and how patent characteristics that are used as proxies for patent value, patent scope/breadth, and patent strength, as well as the nature of patent ownership, influenced the occurrence and frequency of patent ownership change that resulted from mergers, acquisitions, and spin-offs in the agricultural biotechnology sector during the 1980s and 1990s. Our results show that the greater is the breadth of a patent and the less valuable and the 'weaker' is a patent, the greater is the likelihood and frequency of patent ownership change. In addition, we find that patents owned by multiple owners of different nationalities were more likely to change hands.

Our results may be of interest to innovators/'original' patent holders and patent examiners, as they both determine a number of patent characteristics during the patent-granting process,; the former in their patent applications (e.g., patent claims and backward citations) and the latter when they request amendments (to patent claims and citations) and make patent classification assignments.[5]

Our study builds on a rich literature that uses patent characteristics to study innovation, technical change, optimal patent design, and policy and more recently, merger, and acquisition activity. This literature recognizes that, unlike patent counts which, when used alone, are uninformative of the nature and/or value of the inno-

2. *In 1998, five firms (AstraZeneca, DuPont, Monsanto, Novartis, and Aventis) accounted for nearly two-thirds of the global pesticide market (60%), almost one-quarter (23%) of the commercial seed market, and almost all of the transgenic seed market (Johnson & Melkonyan, 2003).*
3. *As an example, in August 1996, Plant Genetic Systems (PGS) was purchased by AgrEvro for $730 million while its prior market capitalization was only $30 million. According to AgrEvo, $700 million of the purchase price was assigned to the valuation of the patent-protected trait technologies owned by PGS (Marco & Rausser, 2008).*
4. *See Yiannaka and Fulton (2006) for a detailed discussion of the critical importance of patent scope/breadth in determining the value of a patent to the innovator.*
5. *For a detailed discussion of the patentee's role in shaping the scope of patent protection, see Yiannaka and Fulton (2006).*

vation protected by the patent, patent characteristics can convey useful information.

Patent characteristics such as patent length (i.e., the statutory life of a patent) and patent breadth/scope (i.e., the technological territory protected by the patent) have been used in the study of optimal patent design (Gallini, 1992; Gilbert & Shapiro, 1990; Hopenhayn & Mitchell, 2001; Takalo, 2001), patenting and licensing behavior (Green & Schotchmer, 1995; Yiannaka & Fulton, 2006), the R&D process, and the pace of future innovations (Denicolo, 1996; Matutes, Regibeau, & Rocket, 1996; O'Donoghue, Scotchmer, & Thisse, 1998). A few empirical studies have tried to 'quantify' the scope/breadth of a patent. These studies have used the number of patent claims, the international patent classification (IPC) assignments,[6] and backward citations[7] as patent breadth indicators (Harhoff & Reitzig, 2004; Lanjouw & Shankerman, 2001; Lerner, 1994). Similarly, a number of studies have tried to estimate the value of a patent. These studies show that the number of forward citations (i.e., citations a patent receives from subsequent patents) is a good proxy for patent value (Hall, Jaffe, & Trajtenberg, 2005; Jaffe, Henderson, & Trajtenberg, 1993; Trajtenberg, 1990).

The impact of certain patent characteristics and patenting patterns on the consolidation of the agricultural biotechnology industry has been considered more recently. King and Schimmelpfennig (2005) used backward and forward patent citations to capture patent quality and measure whether the quality of patents is affected by mergers and acquisitions activity. They compared the number of backward and forward citations for an average patent held by every parent and their subsidiaries. Their results indicate that both types of citations are higher for the parent firms than for their subsidiaries. Brennan, Pray, Naseem, and Oehmke (2005) empirically examined mergers and acquisitions activity by comparing the number of patents held by the top four firms (Monsanto, Pioneer, Novartis, and DuPont) before and after mergers or acquisitions took place. They show that the number of patents held by these firms significantly increased after mergers and acquisitions. The study also examines the performance and concentration of the innovation market in the plant agricultural biotechnology industry. Assuming that market power is related to market share—where market share is defined as the proportion of patents owned or field trials conducted by a firm—they found an increase in the concentration in the innovation market, as measured by the share of the top four firms, with Monsanto being the major force behind the increase. Marco and Rausser (2008) used the average annual forward patent citations, the proportion of backward citations that are self-citations, the number of four-digit IPCs, the age of the patent at the time of litigation and negotiation, and the technology field of the patent as proxies for patent enforceability. They estimated the effect of patent enforceability on the rate at which firms acquire and showed that patent enforceability is significantly and negatively related to merger activity, therefore suggesting that firms that hold weakly-protected patents are more likely to engage in acquisitions than firms that hold strongly-protected patents. Finally, Schimmelpfennig and King (2006) showed that the highest quality patents (measured by forward citations) are less likely to change hands in the agricultural biotechnology sector.

Our study adds to the above literature by examining the impact of various patent characteristics that are used as proxies for patent breadth/scope, patent value, and patent strength on the occurrence and frequency of patent ownership change that resulted from mergers, acquisitions, and spin-offs in the agricultural biotechnology sector during the 1980s and 1990s. The study discusses in detail and provides a justification for the patent characteristics that we use as proxies for the patent qualities considered in our analysis. The patent dataset and the variables used in the analysis are described first, followed by the results of the empirical models and the study's conclusions.

## Data Description

### *Data Source*

Our dataset was obtained from the Agricultural Biotechnology Intellectual Property (ABIP) database, which is made available by the Economic Research Service (ERS) of the US Department of Agriculture (USDA). The ABIP database provides information for US and non-US utility patents on inventions in agricultural biotechnology issued between 1976 and 2000, including information about the ownership of these patents, whether patents are held by the public or private sector, and changes in patent ownership due to firm mergers, acquisitions, and spin-offs between 1988 and 2002.[8]

6. *The IPC classification consists of nine-digit classes of different technologies assigned by the patent examiner to each patent during the patent examination process.*
7. *Backward citations are the number of prior patents and other relevant references that constitute the prior art cited in a patent.*

The database is fully searchable and accessible online[9] and has been used in a number of studies that examine the consolidation of the agricultural biotechnology sector (e.g., Brennan et al., 2005; King & Schimmelpfennig, 2005; Marco & Rausser, 2008; Schimmelpfennig & King, 2006). Our dataset consists of 6,223 private-sector US and non-US agricultural biotechnology patents that were issued by the USPTO between 1976 and 2000 and includes information on the number of patent claims, the assigned IPC codes, nationality of the patent holder, forward and backward citations, and references to the non-patent literature for each patent, as well as changes in patent ownership due to firm mergers, acquisitions, and spin-offs between 1988 and 2002.

## Variables

In what follows, we describe the independent and dependent variables that are used in our analysis and provide a justification for the patent characteristics that we use as proxies for patent breadth, value, and strength.

***Ownership Change.*** Ownership change during the period of our study resulted from mergers, acquisitions, and spin-offs. Schimmelpfennig and King (2006) and King and Schimmelpfennig (2005) utilized ownership change information provided by the ABIP database to examine mergers, acquisitions, and the flows of agricultural biotechnology intellectual property. In this article, we employ a dummy variable to capture the occurrence of patent ownership change (whether the patent changed hands or not) and a variable that has a natural order to capture the frequency of patent ownership change (the number of times a patent has changed hands). In the dataset, 57.37% of all patents did not change hands, 33.92% changed hands once, 8.07% changed hands twice, and 0.64% changed hands three times.

*8. In the database, patents are categorized according to a technology classification system, which includes plant technologies, patented organisms, non-plant, metabolic pathways and biological processes in plants, metabolic pathways and biological processes in animals, protection and nutrition, and biological control of plants and animals, pharmaceuticals, genetic transformation, metabolic pathways and biological processes, DNA-scale, and genomics (Schimmelpfennig & King, 2006).*

*9. See http://webarchives.cdlib.org/sw1m04028n/http://www.ers.usda.gov/data/AgBiotechIP/. The website provides detailed information on the nature of the data and the way it was generated.*

***Number of Total Claims.*** Patent claims are an important feature of a patent since they define the technological territory protected by the patent. In the patent literature, a positive relationship between the number of patent claims and patent breadth is assumed (Matutes et al., 1996; Merges & Nelson, 1990; Miller & Davis, 1990). The number of patent claims has been used as an indicator of patent breadth in a number of patent studies. As an example, the number of total claims is used as a proxy for patent breadth in Lanjouw and Shankerman (2001), who examined the determinants of patent litigation and in Harhoff and Reitzig (2004), who examined the determinants of opposition activity. In line with the above studies, we use the number of total claims as a proxy for patent breadth and seek to examine whether they play a role in patent ownership change.

***International Patent Classification (IPC) Assignments.*** During the USPTO examination, each patent is assigned by the patent examiner to a nine-digit category of the IPC system. Lerner (1994) suggested that IPC classification reflects the economic importance of new inventions and employed the IPC assignments as a proxy for patent scope. According to Lerner (1994), there is a positive relationship between the number of IPC classes and subclasses assigned to a patent and the breadth of the patent; the greater the number of IPC classes and subclasses assigned to the patent, the greater is the breadth of the patent. Lanjouw and Shankerman (2001) used the number of IPC assignments as another proxy for patent breadth (in addition to patent claims) to examine patent litigation patterns and found that patents with many IPC assignments are less likely to be litigated. Harhoff and Reitzig (2004) utilized the number of IPC assignments as another proxy for patent breadth to examine the likelihood of patent opposition. In this article, the count of the number of four-digit IPC subclasses to which a patent is assigned is used as another proxy for patent breadth as in Lerner (1994), Lanjouw and Shankerman (2001), and Harhoff and Reitzig (2004).

***References to Prior Patents (Backward Citations).*** Backward citations are the number of prior patents cited in a patent. Like claims, the citations define the property rights of the patentee. Harhoff and Reitzig (2004) employed backward citations to capture the likelihood of patent opposition while Lanjouw and Shankerman (2001) examined the effect of backward citations in litigation activity as failure to cite relevant patents is grounds for having the patent invalidated.[10]

For our analysis, we count the overall number of backward citations listed in the patent and use them in two ways—as another proxy for patent breadth and as a proxy for how prone the patent is to litigation and invalidation (i.e., patent strength). As suggested by Trajtenberg (1990, p. 174) "[patent citations] represent a limitation on the scope of the property rights established by a patent's claim." Thus, according to Trajtenberg, there is a negative relationship between the number of backward citations and the breadth of patent protection as, the greater is the number of studies/patents cited as prior art in any given patent, the smaller is the technological territory over which claims can be made by that patent. On the other hand, as suggested by Lanjouw and Shankerman (2001), the smaller the number of backward citations, the greater the risk that the innovator failed to reference the relevant literature and, thus, the greater the risk of patent litigation and invalidation. Thus, when deciding on the number of backward citations to be included in the patent, the innovator faces a trade-off; a small number of backward citations suggest greater patent breadth but also greater likelihood of patent litigation and invalidation and consequently, a 'weaker' patent.

***References to Non-Patent Literature.*** Scientific knowledge is referenced by patentees while patent examiners search for relevant references in the scientific literature, since results from published research can be used to confirm the state of the art against which the application has to be evaluated. Harhoff and Reitzig (2004) used references to non-patent literature as an indicator of patent value—where the larger the number of these references, the higher the patent value—and suggested that patents with a large number of references to non-patent literature would face a higher likelihood of opposition. However, as was discussed in the case of backward citations, failure to cite prior art may lead to patent invalidation, which in turn implies that the greater is the number of references to non-patent literature, the greater is the likelihood of patent invalidation. In addition, when the references involve various scientific fields, a greater number of references may indicate a broader patent. In this article, we want to examine whether and how the number of references to non-patent literature affects the incidence and frequency of ownership change. Given the lack of consensus in the literature as to what this variable could capture, we will be cautious when interpreting its potential effect on the incidence and frequency of ownership change.

***Citations Received from Succeeding Patents (Forward Citations).*** Citations received by a patent from future patents are indicative of its contribution to the state of the art. Forward citations have been widely used in the patent literature. For example, Lanjouw and Shankerman (2001) used forward citations as an indicator of patent value to investigate its relationship with litigation activity and find that more valuable patents (i.e., patents with more forward citations) are more likely to be litigated. Schimmelpfennig and King (2006) viewed forward citations as a measure of patent quality and employed them to analyze the diffusion of knowledge among different technology classifications in the agricultural biotechnology industry. King and Schimmelpfennig (2005) used forward citations as an indicator of patent quality to examine whether the quality of patents was affected by merger and acquisition activity. Similar to the above studies, we use forward citations as a measure of patent value and examine their effect on the incidence and frequency of patent ownership change.

***Patent Ownership.*** The patent holder may be an individual, a firm, a non-profit organization, or a group of individuals and firms. The nationality of patent ownership is that of the assignee, or otherwise it is the nationality of the inventor. We create dummy variables to account for patent owners from the United States, Europe, Canada, Japan, Australia, and New Zealand, and group the remaining ones as patent owners from the Rest of the World (RoW). In addition, we create a dummy variable to account for patents owned by owners of different nationalities. The effect of these variables on changes in patent ownership is examined.

## Descriptive Statistics and Empirical Results

### *Descriptive Statistics*

The empirical analysis is based on data covering private-sector US and non-US patents in the agricultural

10. *Backward citations have been used in a number of studies, such as Jaffe et al. (1993), who examined the impact of citations to previous patents in the geographical localization of the technological activity; Jaffe and Trajtenberg (1996), who used backward citations to analyze the process by which existing knowledge is transferred over time to different locations; and Jaffe and Trajtenberg (1999), who measured knowledge flows based on the information revealed by backward citations.*

**Table 1. Descriptive statistics for the agricultural biotechnology patents (N=6,223).**

| Variable | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| **Number of IPC assignments** | 1.894 | 0.778 | 1 | 7 |
| **Number of independent claims** | 2.885 | 2.797 | 1 | 69 |
| **Number of dependent claims** | 13.45 | 13.315 | 0 | 184 |
| **Number of total claims** | 16.338 | 14.425 | 1 | 196 |
| **Number of backward citations** | 6.768 | 9.938 | 0 | 196 |
| **Number of references to non-patent literature** | 14.283 | 23.669 | 0 | 535 |
| **Number of total backward citations** | 21.051 | 30.579 | 0 | 731 |
| **Number of forward citations** | 7.381 | 17.222 | 0 | 549 |
| **Owner from US** | 0.621 | 0.485 | 0 | 1 |
| **Owner from Europe** | 0.240 | 0.427 | 0 | 1 |
| **Owner from Canada** | 0.010 | 0.099 | 0 | 1 |
| **Owner from Japan** | 0.106 | 0.308 | 0 | 1 |
| **Owner from Australia and New Zealand** | 0.008 | 0.087 | 0 | 1 |
| **Owner from the rest of the world (RoW)** | 0.006 | 0.077 | 0 | 1 |
| **Owner from multiple countries** | 0.007 | 0.085 | 0 | 1 |

biotechnology industry that were granted by the USPTO between 1976 and 2000. The complete dataset contains 6,223 US and non-US patents and includes information on patent claims, assigned IPC codes, the nationality of the patent holder, forward and backward citations, and references to the non-patent literature for each patent.

Summary statistics for the patents in our sample are given in Table 1. The patents have, on average, 1.894 IPC classifications. Independent claims range from 1 to 69 while dependent claims range from 0 to 184 with an average of 13.45 total claims per patent. Forward citations range from 0 to 549 citations per patent, with an average of about 7.381 citations per patent; citations to prior patents range from 0 to 196 at an average of about 6.768 citations per patent; citations to non-patent literature range from 0 to 535, while total backward citations (i.e., patent and no patent literature) range from 0 to 731 with an average of 21 citations per patent. American nationals own the largest share of patents with 62.1%, followed by Europeans who own 24%, Japanese who own 10.6 %, Canadians who own 1%, Australian and New Zealanders who own 0.8%, and owners from other countries who own 0.6% of the patents granted. Meanwhile, only 0.7% of the patents have owners from more than one country.

Tables 2, 3, and 4 show the relationships between the incidence of ownership change and three of the exogenous variables—namely, backward citations, forward citations, and references to the non-patent literature, respectively. To assess these relationships, we use the Pearson's chi-square test, which is commonly used to assess independence between paired observations of two variables. The null hypothesis holds that there is no relationship between the incidence of ownership change and backward citations (Table 2), forward citations (Table 3), and references to the non-patent literature (Table 4).[11] The three tables present data on the univariate distribution of the exogenous variables as well as data on the bivariate relationship between these variables and the incidence of ownership change. These statistics are presented for the total number of patents in our sample and, separately, based on patent ownership for US patent owners, European patent owners, and patent owners from the rest of the countries, which are grouped together.

According to Table 2, backward citations are highly correlated with the likelihood of ownership change both in the overall sample of backward citations and in each of the sub-groups. The group of patents that did not receive backward citations changed ownership in 49.4% of all cases. This is the group with the highest probability that a patent will change hands. For the same class, European patents and patents with owners from the rest of the countries have changed their ownership more than US patents (60.5% and 60.6% compared to 54%, respectively). However, within each of the sub-groups of European patents, US patents, and patents with owners from the rest of the countries, there is no clear trend of how the number of backward citations affects the incidence of ownership change. For example, in the subgroup of the US patent owners, patents with no backward citations have the greatest probability of changing hands (54%), followed by patents that received 1-5 backward citation (53.9% of all the cases). While, in the sub-group of European patents, the group of patents that does not receive backward citations changed ownership in 60.5% of all cases. The second group with the highest probability of ownership change is the group of patents that received 11-15 backward citations.

11. *The results of the Pearson's chi square test are evaluated by reference to the chi-square distribution.*

**Table 2. Backward citations and incidence of ownership change.**

| Number of backward citations | Number of patents | % of total patents | Incidence of ownership change: All patents | Incidence of change: US owners | | Incidence of change: European owners | | Incidence of change: Patents of other owners | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Patents | Mean | Patents | Mean | Patents | Mean |
| **0** | 820 | 13.18 | 0.494 | 574 | 0.540 | 147 | 0.605 | 99 | 0.606 |
| **1 - 5** | 2,977 | 47.84 | 0.429 | 1,793 | 0.539 | 738 | 0.343 | 446 | 0.13 |
| **6 - 10** | 1,216 | 19.54 | 0.365 | 665 | 0.451 | 338 | 0.325 | 213 | 0.159 |
| **11 - 15** | 560 | 9.00 | 0.418 | 357 | 0.440 | 139 | 0.446 | 64 | 0.234 |
| **>15** | 650 | 10.45 | 0.457 | 479 | 0.474 | 135 | 0.444 | 36 | 0.278 |
| **Total** | 6,223 | 100.00 | 0.427 | 3,868 | 0.507 | 1497 | 0.383 | 858 | 0.143 |
| **p-value** | | | (0.000) | | (0.000) | | (0.000) | | (0.000) |

*Note: The p-value refers to a Pearson test of the hypothesis that there is no relationship between the number of backward citations and the incidence of ownership change.*

**Table 3. Forward citations and incidence of ownership change.**

| Number of forward citations | Number of patents | % of total patents | Incidence of ownership change: All patents | Incidence of change: US owners | | Incidence of change: European owners | | Incidence of change: Patents of other owners | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Patents | Mean | Patents | Mean | Patents | Mean |
| **0** | 1,457 | 23.40 | 0.463 | 820 | 0.572 | 407 | 0.415 | 230 | 0.156 |
| **1 - 5** | 2,898 | 46.60 | 0.418 | 1,681 | 0.508 | 768 | 0.392 | 449 | 0.125 |
| **6 - 10** | 788 | 12.70 | 0.410 | 508 | 0.482 | 181 | 0.343 | 99 | 0.162 |
| **11 - 15** | 358 | 5.70 | 0.388 | 262 | 0.439 | 59 | 0.305 | 37 | 0.162 |
| **>15** | 722 | 11.60 | 0.429 | 597 | 0.464 | 82 | 0.293 | 43 | 0.203 |
| **Total** | 6,223 | 100.00 | 0.427 | 3,868 | 0.507 | 1,497 | 0.383 | 858 | 0.143 |
| **p-value** | | | (0.000) | | (0.000) | | (0.000) | | (0.000) |

*Note: The p-value refers to a Pearson test of the hypothesis that there is no relationship between the number of forward citations and the incidence of ownership change.*

Table 3 shows that there is a significant relationship between forward citations and the incidence of ownership change. This is true for the sub-groups of US patents, European patents, and patents from the rest of the countries. Again, the patents that do not receive any citations (i.e., 57.2% of US patents, 41.5% of European patents) are the ones whose ownership changed more often. Meanwhile, the patents of other owners that received 6-15 forward citations changed their ownership more often (16.2% of each subgroup of 6-10 citations and 11-15 citations).

Table 4 represents the relationship between the incidence of ownership change and references to the non-patent literature. In the overall sample as well as in the sub-groups of patents, we find a significant relationship between the incidence of ownership change and references to the non-patent literature. Evidence shows that as the number of references increases, the occurrence of ownership change increases too in the overall sample and for the US and European owned patents (no clear trend exists for patents with owners from the rest of the countries). Thus, patents with more than 15 citations to the non-patent literature changed hands more than other patents—54.1% in the overall sample, 56.9% for patents of US owners, and 50.9% for patents of European owners.

Table 5 provides a general view of the correlation between all independent variables. There are a few coefficients that indicate strong correlations between certain variables. For example, the number of total backward citations and the number of reference to non-patent literature have a correlation coefficient of 0.863. Also, the number of total backward citations and the number of backward citations have a correlation coefficient of 0.665. The explanation for these coefficients is that the number of total backward citations is comprised of the number of references to the non-patent literature and the number of backward citations. A positive relationship (0.955) exists between the number of dependent claims and number of total claims, since the dependent claims are included in the number of total claims.

**Table 4. References to the non-patent literature and incidence of ownership change.**

| Number of references to the non-patent literature | Number of patents | % of total patents | Incidence of ownership change | Incidence of change: US owners | | Incidence of change: European owners | | Incidence of change: Patents of other owners | |
|---|---|---|---|---|---|---|---|---|---|
| | | | All patents | Patents | Mean | Patents | Mean | Patents | Mean |
| **0** | 921 | 14.80 | 0.321 | 503 | 0.384 | 291 | 0.302 | 127 | 0.118 |
| **1 - 5** | 1,696 | 27.25 | 0.353 | 864 | 0.471 | 481 | 0.319 | 351 | 0.108 |
| **6 - 10** | 1,054 | 16.94 | 0.398 | 591 | 0.486 | 267 | 0.4 | 196 | 0.133 |
| **11 - 15** | 694 | 11.15 | 0.484 | 465 | 0.540 | 142 | 0.451 | 87 | 0.241 |
| **>15** | 1,858 | 29.86 | 0.541 | 1,445 | 0.569 | 316 | 0.509 | 97 | 0.237 |
| **Total** | 6,223 | 100.00 | 0.427 | 3,868 | 0.507 | 1,497 | 0.383 | 858 | 0.143 |
| **p-value** | | | (0.000) | | (0.000) | | (0.000) | | (0.000) |

*Note: The p-value refers to a Pearson test of the hypothesis that there is no relationship between the number of references to the non-patent literature and the incidence of ownership change within the indicated group of patents.*

**Table 5. Correlation matrix for the independent variables in the probit models.**

| Independent variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **1. ln (1 + number of backward citations)** | 1.000 | | | | | | | |
| **2. ln (1 + number of references to non-patent literature)** | 0.288 | 1.000 | | | | | | |
| **3. ln (1 + number of total backward citations)** | 0.665 | 0.863 | 1.000 | | | | | |
| **4. ln (1 + number of forward citations)** | 0.154 | 0.075 | 0.143 | 1.000 | | | | |
| **5. ln (number of IPC assignments)** | 0.032 | 0.084 | 0.063 | 0.039 | 1.000 | | | |
| **6. ln (number of total claims)** | 0.151 | 0.216 | 0.223 | 0.109 | 0.138 | 1.000 | | |
| **7. ln (1 + number of dependent claims)** | 0.143 | 0.179 | 0.191 | 0.096 | 0.118 | 0.955 | 1.000 | |

## Empirical Results

### *Ownership Change*

A probit regression was employed to explore how the set of the following covariates affect the (conditional) probability that a patent changes ownership: the total number of patent claims, the IPC assignments, the number of backward citations, the number of references to the non-patent literature, the number of forward citations, and a set of ownership dummy variables that account for nationality differences.[12] The probit regression was run two times; first with the Newton-Raphson method (white covariance-heteroskedasticity corrected; see Table 6, Column 1), and second with the Brendt-Hall-Hall-Hausman (BHHH) method (Table A1, Column 5 in the Appendix). The Newton-Raphson method was chosen to correct heteroskedasticity problems detected using the White Heteroskedasticity test (see Table A2, in the Appendix).[13] Both estimation methods of Newton-Raphson and BHHH converge to the same results. This indicates that our model is robust.

The results for the likelihood of ownership change are summarized in Table 6. We report the probit coefficients and their respective standard errors in Column 1. In Column 2, we present the marginal effects of the independent variables at the sample mean and the respective standard errors.

Estimation results show that the number of total claims—which is one of the proxies for patent breadth—does not have a statistically significant effect on the incidence of ownership change in our data. Even though its coefficient is positive, indicating that broader patents (patents with more claims) are more likely to be traded, it is not statistically significant. The number of IPC assignments—which is also a proxy for patent breadth—has a positive and statistically significant (at the 1% confidence level) effect on the likelihood of ownership change. The above imply that broader patents (i.e., patents with more IPC assignments) are more

12. *To account for the skewed distribution of the independent variables (see Table 1), we use a logarithmic transformation on each variable.*

13. *Based on the F-statistic (68.776) and the probability values (0.000), the null hypothesis that there is no heteroskedasticity was rejected.*

**Table 6. Probit model of ownership change.**

| Independent variable | 1<br>Coefficient (S.E.) | 2<br>Marginal effect (S.E) |
|---|---|---|
| **ln (number of total claims)** | 0.033<br>(0.020) | 0.013<br>(0.08) |
| **ln (number of IPC assignments)** | 0.105**<br>(0.040) | 0.041**<br>(0.015) |
| **ln (1 + number of backward citations)** | -0.118***<br>(0.018) | -0.046***<br>(0.007) |
| **ln (1 + number of references to non-patent literature)** | 0.147***<br>(0.014) | 0.057***<br>(0.005) |
| **ln (1 + number of forward citations)** | -0.068***<br>(0.015) | -0.027***<br>(0.006) |
| **Owner from US** | 0.827***<br>(0.207) | 0.305***<br>(0.067) |
| **Owner from Europe** | 0.554**<br>(0.209) | 0.217**<br>(0.077) |
| **Owner from Canada** | 0.676**<br>(0.264) | 0.263**<br>(0.091) |
| **Owner from Japan** | -0.442*<br>(0.218) | -0.162*<br>(0.070) |
| **Owner from RoW** | -1.127*<br>(0.483) | -0.324***<br>(0.076) |
| **Multiple countries** | 0.809**<br>(0.277) | 0.309***<br>(0.091) |
| **Constant** | -0.996***<br>(0.204) | |
| **Log likelihood** | -426.827 | |
| **$\chi^2$** | 6.827.392 | |
| **Probability ($\chi^2$)** | 0.000 | |
| **Pseudo $R^2$ (%)[a]** | 8.038 | |

**, **, *** Significant at 0.05, 0.01, and 0.001 levels, respectively*

[a] *Likelihood ratio index according to McFadden*

likely to be traded. The marginal effect of the IPC assignments shows that an increase in the number of IPC assignments by one standard deviation (0.778) from its mean (1.894) increases the likelihood of patent ownership change by 4.1% points (see Table 1 for mean and standard deviation values).

As discussed earlier, the number of backward citations that refer to patent literature captures both patent breadth (i.e., a high number of backward citations indicates a narrower patent) and the degree of how prone a patent is to litigation and invalidation (i.e., a high number of backward citations indicates a 'stronger' patent). The coefficient of the number of backward citations is negative and statistically significant at the 0.1% confidence level. This result implies that the greater is the number of backward citations and thus the narrower and 'stronger' is the patent, the lower is the likelihood of ownership change. As was the case with the number of IPC assignments, this variable shows that broader patents are more likely to change hands. The marginal effect of the number of backward citations indicates that an increase in the number of backward citations from the sample mean of 6.768 to 16.706 (a shift of about one standard deviation) decreases the likelihood of ownership change by 4.6% points.

The number of references to non-patent literature has a positive and statistically significant (at the 0.1% level of confidence) effect on ownership change. A large number of references to non-patent literature is associated with a greater likelihood of ownership change. As discussed previously, this variable has been interpreted in various ways. Given that a large number of references to the non-patent literature may imply a broader patent, the positive effect of this variable on ownership change suggests that broader patents are more likely to change hands. The marginal effect of the number of references to non-patent literature shows that an increase in the number of references to the non-patent literature from the sample mean of 14.283 to 37.952 increases the likelihood of ownership change by 5.7% points.

The number of forward citations is a measure of patent value. The coefficient of the number of forward citations is negative and statistically significant at the 0.1% confidence level. This result implies that a patent with a large number of forward citations—or otherwise, a high-value patent—is less prone to ownership change. This variable indicates that more valuable patents are less likely to change hands. The marginal effect is negative (-2.7%) and shows that an increase in the number of received citations from 7.381 to 24.602 decreases the likelihood of a patent changing hands by 2.7% points.

The nationality of the patent owner seems to play a significant role in the incidence of ownership change as all coefficients of the nationality of ownership variables are highly significant. The results show that the patents most likely to change hands are patents owned by multiple owners of different nationalities. The incidence of ownership change for these patents is 30.9%. Patents owned by US owners face the second-highest incidence of ownership change (30.5%), followed by patents owned by Canadian owners (26.3%) and European owners (21.7%). Patents that are the least likely to change hands—that is, patents whose ownership type has a negative effect on ownership change—are patents owned by RoW owners; these patents face a decrease in the likelihood of ownership change by 32.4%, followed by patents of Japanese owners, which face a decrease in the likelihood of ownership change by 16.2% points.[14]

From the above results, the proxies for patent breadth—the number of IPC assignments, the number of backward citations, and reference to non-patent literature—indicate that the greater is the patent breadth, the greater is the likelihood of ownership change. On the other hand, the number of backward citations (an indicator of patent strength) and number of forward citations (an indicator of patent value) show that “strong” and high-value patents are less likely to be traded.

### *Frequency of Ownership Change*

The frequency of ownership change is a polychotomous variable that measures how many times a patent has changed hands. Patents in the dataset changed hands up to three times. Ordered probit regressions were employed to examine the effect of the model covariates (the total number of patent claims, the IPC assignments, the number of backward citations, the number of references to the non-patent literature, the number of forward citations, and a set of ownership dummy variables that account for nationality differences) on the frequency of ownership change. Table 7 summarizes these results. We report the probit coefficients and their respective standard errors in Column 1. Their marginal effects are presented in Columns 2 to 5. Similar to the ownership change estimation, the ordered probit regression is run twice—first using the Newton-Raphson method (Table 7, Column 1) and second using the BHHH method (Table A3, Column 5 in the Appendix). The Newton-Raphson is used to correct the heteroskedasticity problems in the data, which were detected by the White Heteroskedasticity test (see Table A4 in the Appendix). Similar to the regressions of ownership change, both methods of estimation converge to the same results, indicating that the model is robust.

The estimation results show that the number of total claims has a significant effect in the frequency of ownership change. Its effect is positive, indicating that the greater is the number of total claims, and thus the broader is the patent, the greater is the frequency of ownership change. The results show that an increase from 16.338 to 30.763 (one standard deviation from the mean) increases the likelihood that a patent changes hands for the first time by 1.1% points, for the second time by 0.5% points, and for the third time by 0.06% points.

Contrary to the results for the ownership change, the number of the IPC assignments cannot statistically explain the frequency of ownership change. Although the coefficient of this variable is positive (0.050), its statistical significance is very low. Also, its marginal effects (0.012, 0.006 and 0.001) are not statistically significant. The number of backward citations, which is an indicator of both patent breadth and how prone the patent is to litigation and invalidation, is found significant at the 0.1% confidence level. Its negative coefficient (-0.121) shows that, as in the case of ownership change, a large number of backward citations (which implies a narrower patent scope and a ‘stronger’ patent) is associated with a lower frequency of ownership change. Its marginal effects indicate that an increase in the number of backward citations by one standard deviation from the mean decreases the likelihood of the patent changing hands for the first time by 3% points, for the second time by 1.5% points, and for the third time by 0.2% points. Clearly, a shift by one standard deviation from the mean affects mostly the first ownership change and then its effect decreases as the frequency of ownership change increases.

The number of references to non-patent literature has a significant effect on the frequency of ownership change. The coefficient of this variable is positive (0.089) and is highly significant (0.1% level of confidence), indicating that a large number of references to non-patent literature increases the frequency of ownership change. The marginal effects show that an increase of about one standard deviation (23.669) from its mean (14.283) increases the likelihood of ownership change for the first time by 2.2% points, for the second time by 1.1% points, and for the third time by 0.1% points.

Finally, the nationality of the patent owner has similar effects on the frequency of ownership change as on the incidence of ownership change. Patents that are the most likely to change hands for the first time are patents owned by US owners (16.7%), followed by patents owned by multiple owners of different nationalities (12.0%), European owners (11.2%), and Canadian owners (9.8%). However, patents with the highest likelihood of changing hands for a second time are patents owned by multiple owners of different nationalities (12.0%), followed by patents owned by Canadian owners (7.7%). Finally, patents that are more likely to change hands for a third time are those owned by multiple owners of different nationalities (2.1%), followed by patents owned

14. *Note that RoW owners own 0.6%, while Japanese owners own 10.6% of all patents in our dataset.*

**Table 7. Probit models of the frequency of ownership change.**

| Independent variable (Frequency of ownership change) | Coefficient (S.E.) | Marginal effect Fr=0 (S.E.) | Fr=1 (S.E.) | Fr=2 (S.E.) | Fr=3 (S.E.) |
|---|---|---|---|---|---|
| **ln (number of total claims)** | 0.045* (0.019) | -0.017* (0.007) | 0.011* (0.004) | 0.005* (0.002) | 0.0006* (0.000) |
| **ln (number of IPC assignments)** | 0.050 (0.037) | -0.019 (0.014) | 0.012 (0.009) | 0.006 (0.004) | 0.001 (0.000) |
| **ln (1 + number of backward citations)** | -0.121*** (0.017) | 0.047*** (0.006) | -0.030*** (0.004) | -0.015*** (0.002) | -0.002*** (0.000) |
| **ln (1 + number of references to non-patent literature)** | 0.089*** (0.014) | -0.034*** (0.005) | 0.022*** (0.003) | 0.011*** (0.001) | 0.001*** (0.000) |
| **ln (1 + number of forward citations)** | -0.055*** (0.013) | 0.021*** (0.005) | -0.014*** (0.003) | -0.006*** (0.001) | -0.0007** (0.000) |
| **Owner from US** | 0.668** (0.216) | -0.249*** (0.066) | 0.167*** (0.044) | 0.074*** (0.019) | 0.008** (0.002) |
| **Owner from Europe** | 0.489** (0.218) | -0.192** (0.074) | 0.112** (0.037) | 0.071* (0.031) | 0.009 (0.005) |
| **Owner from Canada** | 0.473* (0.260) | -0.187* (0.091) | 0.098** (0.035) | 0.077 (0.048) | 0.011 (0.009) |
| **Owner from Japan** | -0.621** (0.226) | 0.218*** (0.060) | -0.159*** (0.048) | -0.054*** (0.011) | -0.004*** (0.001) |
| **Owner from RoW** | -1.268** (0.479) | 0.344*** (0.061) | -0.275*** (0.057) | -0.064*** (0.005) | -0.004*** (0.000) |
| **Multiple countries** | 0.673** (0.271) | -0.262** (0.091) | 0.120*** (0.019) | 0.120* (0.058) | 0.021 (0.015) |
| $\gamma_1$ | | | 0.752*** (0.224) | | |
| $\gamma_2$ | | | 1.989*** (0.226) | | |
| $\gamma_3$ | | | 3.144*** (0.231) | | |
| **Log likelihood** | | | -5.731.606 | | |
| $\chi^2$ | | | 6.177.150 | | |
| **Probability ($\chi^2$)** | | | 0.000 | | |
| **Pseudo $R^2$ (%)**[a] | | | 5.388 | | |

**, **, *** Significant at the 0.05, 0.01, and 0.001 levels, respectively*
*[a] Likelihood ratio index according to McFadden.*

by Canadian owners (1.1%), European owners (0.9%), and US owners (0.8%).

As in the case of occurrence of ownership change, patents owned by RoW owners and Japanese owners are the least likely to change ownership (the effect of these ownership types on the frequency of ownership change is negative). Patents owned by RoW and Japanese owners face a decrease in the likelihood of a first ownership change by 27.5% and 15.9%, of a second change by 6.4% and 5.4% and of a third change by 0.4% and 0.4%, respectively. Overall, the results show that the greater is the patent breadth, the greater is the frequency of ownership change. Also, the less valuable and the 'weaker' is a patent, the more likely it is that it will be traded more than once.

## Conclusions

Intellectual property rights and, most notably, patents are essential assets for firms that compete in globalized markets where innovation is critical for their economic performance. Firms develop their own intellectual properties/technologies, license them from other firms, and/or acquire them through mergers and acquisitions. Control over patent rights played an important role in the consolidation experienced by the agricultural biotechnology sector in the 1980s and 1990s.

Trying to gain insights on the role certain patent qualities may play in the transfer of knowledge and technology that takes place through mergers and acquisitions, this study examined how a patent's breadth/scope, value, and strength affected the occurrence and frequency of patent ownership change that resulted from mergers, acquisitions, and spin-offs in the agricultural biotechnology sector in the 1980s and 1990s. The study used a dataset of private-sector US and non-US agricultural biotechnology patents that were granted by the USPTO during the period of 1976-2000 and a number of patent characteristics as proxies for patent breadth, patent value, and patent strength. Specifically, the number of total claims and the number of IPC assignments were used as proxies for patent breadth; backward citations (references to prior patents) and references to the non-patent literature were used as proxies for both patent breadth and patent strength, while forward citations (citations received from succeeding patents) were used to measure the value of the patent.

The discrete probit model was used to examine the role of patent strength, patent breadth, patent value, and the nationality of the patent owner in the occurrence of patent ownership change; the ordered probit model was used to examine whether and how these characteristics affected the frequency of patent ownership change. The empirical results of the probit model showed that patent breadth indicators such as the number of IPC assignments, the number of backward citations and references to non-patent literature suggest that the greater is patent breadth, the greater is the likelihood of patent ownership change. On the other hand, the number of backward citations—which was used as an indicator of patent strength—and the number of forward citations—which was used as an indicator of patent value—suggest that 'strong' and high-value patents were less likely to be traded. In addition, patents that were most likely to change hands were those owned by multiple owners of different nationalities. Overall, the nationality of the patent holder had the greatest impact on the incidence of ownership change, followed by the number of references to non-patent literature, the number of backward citations, the number of IPC assignments, and the number of forward citations. The results of the ordered probit model suggest a positive relationship between patent breadth and the frequency of ownership change. In addition, the less valuable and the 'weaker' is the patent, the more likely it is that the patent will change hands more than once.

It is important to note that accurately measuring or quantifying patent characteristics such as patent breadth, patent strength, and patent value is not an easy task. For instance, it is not just the number of patent claims but also the language in the claims that determine the breadth/scope of protection. However, the interpretation of the language in the claims can be subjective, limiting its use as a measure of patent breadth in empirical research. Recognizing these limitations, we used the insights and findings of a large number of patent studies to identify the proxies that we used as indicators of patent breadth, patent value, and patent strength.

Our results may be of interest to innovators/patent applicants who determine a number of patent characteristics in their patent application and can further refine them during the patent-granting process by helping them understand how their decisions affect the commercial and strategic value of their patents.

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## Appendix

See next page.

**Table A1. Probit models of the ownership change.**

| Independent variable (Ownership change) | Model 1<br>Coefficient (S.E.) | Model 2<br>Coefficient (S.E.) | Model 3<br>Coefficient (S.E.) | Model 4<br>Coefficient (S.E.) | Final model (BHHH method)<br>Coefficient (S.E.) |
|---|---|---|---|---|---|
| **ln (number of total claims)** | 0.036<br>(0.020) | | | | 0.033<br>(0.020) |
| **ln (number of independent claims)** | | 0.012<br>(0.025) | 0.015<br>(0.025) | 0.016<br>(0.025) | |
| **ln (1 + number of dependent claims)** | | 0.034<br>(0.019) | 0.034<br>(0.019) | 0.034<br>(0.019) | |
| **ln (number of IPC assignments)** | 0.119**<br>(0.039) | 0.102**<br>(0.040) | 0.103**<br>(0.040) | 0.103**<br>(0.040) | 0.105**<br>(0.040) |
| **ln (1 + number of total backward citations)** | 0.072***<br>(0.016) | | | | |
| **ln (1 + number of backward citations)** | | -0.118***<br>(0.018) | -0.119***<br>(0.018) | -0.119***<br>(0.018) | -0.118***<br>(0.018) |
| **ln (1 + number of references to non-patent literature)** | | 0.147***<br>(0.014) | 0.145***<br>(0.014) | 0.145***<br>(0.014) | 0.147***<br>(0.014) |
| **ln (1 + number of forward citations)** | -0.082***<br>(0.014) | -0.067***<br>(0.015) | -0.069***<br>(0.015) | -0.069***<br>(0.015) | -0.068***<br>(0.015) |
| **Owner from US** | 0.675***<br>(0.119) | 0.669***<br>(0.121) | 0.067<br>(0.182) | 1.977***<br>(0.432) | 0.827***<br>(0.207) |
| **Owner from Europe** | 0.349**<br>(0.121) | 0.397**<br>(0.124) | -0.205<br>(0.184) | 1.704***<br>(0.433) | 0.554**<br>(0.209) |
| **Owner from Canada** | 0.495*<br>(0.199) | 0.515*<br>(0.204) | -0.085<br>(0.245) | 1.824***<br>(0.462) | 0.676**<br>(0.264) |
| **Owner from Japan** | -0.654***<br>(0.136) | -0.596***<br>(0.138) | -1.199***<br>(0.194) | 0.709***<br>(0.437) | -0.442*<br>(0.218) |
| **Owner from Australia and New Zealand** | | | -0.734***<br>(0.277) | 1.175**<br>(0.480) | |
| **Owner from RoW** | | | -1.888***<br>(0.472) | | -1.127*<br>(0.483) |
| **Multiple countries** | | | | 1.962***<br>(0.469) | 0.809**<br>(0.277) |
| **Constant** | -0.890***<br>(0.132) | -0.840***<br>(0.130) | -0.234<br>(0.188) | -2.143***<br>(0.434) | -0.996***<br>(0.204) |
| **Log likelihood** | -3.969.488 | -3.918.605 | -3.905.467 | -3.904.223 | -426.827 |
| $\chi^2$ | 554..6793 | 6.564.449 | 6.827.207 | 6.852.098 | 6.827.392 |
| **Probability ($\chi^2$)** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Pseudo $R^2$ (%)** | 6.531 | 7.728 | 8.038 | 8.067 | 8.038 |

**Table A2. White heteroskedasticity test of ownership change models.**

| | F-Static | Probability | Obs*R-squared | Probability |
|---|---|---|---|---|
| **Model 1** | 112.350 | 0.000 | 1110.036 | 0.000 |
| **Model 2** | 62.235 | 0.000 | 860.434 | 0.000 |
| **Model 3** | 61.211 | 0.000 | 938.500 | 0.000 |
| **Model 4** | 61.577 | 0.000 | 943.2715 | 0.000 |
| **Final model** | 68.776 | 0.000 | 937.2510 | 0.000 |

**Table A3. Probit models of the frequency of ownership change.**

| Independent variable (Frequency of ownership change) | Model 1 Coefficient (S.E.) | Model 2 Coefficient (S.E.) | Model 3 Coefficient (S.E.) | Model 4 Coefficient (S.E.) | Final model (BHHH method) Coefficient (S.E.) |
|---|---|---|---|---|---|
| **ln (number of total claims)** | 0.046* (0.018) | | | | 0.045* (0.019) |
| **ln (number of independent claims)** | | -0.025 (0.023) | -0.022 (0.024) | -0.022 (0.024) | |
| **ln (1 + number of dependent claims)** | | 0.051** (0.017) | 0.050** (0.018) | 0.050** (0.018) | |
| **ln (number of IPC assignments)** | 0.063 (0.037) | 0.052 (0.037) | 0.052 (0.037) | 0.052 (0.037) | 0.050 (0.037) |
| **ln (1 + number of total backward citations)** | 0.011 (0.015) | | | | |
| **ln (1 + number of backward citations)** | | -0.121*** (0.016) | -0.122*** (0.017) | -0.122*** (0.017) | -0.121*** (0.017) |
| **ln (1 + number of references to non-patent literature)** | | 0.094*** (0.013) | 0.092*** (0.014) | 0.092*** (0.014) | 0.089*** (0.014) |
| **ln (1 + number of forward citations)** | -0.067*** (0.013) | -0.053*** (0.0013) | -0.055*** (0.013) | -0.055*** (0.013) | -0.055*** (0.013) |
| **Owner from US** | 0.575*** (0.121) | 0.564*** (0.113) | 0.665** (0.217) | 1.948*** (0.427) | 0.668** (0.216) |
| **Owner from Europe** | 0.352** (0.124) | 0.384*** (0.116) | 0.484* (0.218) | 1.767*** (0.428) | 0.489** (0.218) |
| **Owner from Canada** | 0.345 (0.184) | 0.363 (0.187) | 0.465 (0.260) | 1.748*** (0.450) | 0.473* (0.260) |
| **Owner from Japan** | -0.766*** (0.136) | -0.719*** (0.131) | -0.621*** (0.226) | 0.661 (0.432) | -0.621** (0.121) |
| **Owner from Australia and New Zealand** | | | | 1.311** (0.480) | |
| **Owner from RoW** | | | -1.262** (0.482) | | -1.268** (0.479) |
| **Multiple countries** | | | | 1.948*** (0.457) | 0.673** (0.271) |
| $\gamma_1$ | 0.675*** (0.131) | 0.647*** (0.122) | 0.741*** (0.223) | 2.024*** (0.428) | 0.752*** (0.224) |
| $\gamma_2$ | 1.900*** (0.134) | 1.882*** (0.124) | 1.979*** (0.225) | 3.261*** (0.429) | 1.989*** (0.226) |
| $\gamma_3$ | 2.050*** (0.140) | 3.037*** (0.134) | 3.135*** (0.230) | 4.417*** (0.432) | 3.144*** (0.231) |
| **Log likelihood** | -57.313.279 | -5.731.606 | -5.421.495 | -5.420.996 | -5.731.606 |
| $\chi^2$ | 5.133.279 | 5.915.789 | 6.202.213 | 6.212.205 | 6.177.150 |
| **Probability ($\chi^2$)** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Pseudo $R^2$ (%)** | 4.478 | 5.161 | 5.410 | 5.419 | 5.388 |

**Table A4. White heteroskedasticity test of frequency of ownership change models.**

| | F-Static | Probability | Obs*R-squared | Probability |
|---|---|---|---|---|
| **Model 1** | 21.600 | 0.000 | 249.336 | 0.000 |
| **Model 2** | 17.878 | 0.000 | 274.205 | 0.000 |
| **Model 3** | 16.779 | 0.000 | 288.897 | 0.000 |
| **Model 4** | 16.825 | 0.000 | 289.644 | 0.000 |
| **Final model** | 17.854 | 0.000 | 273.843 | 0.000 |