The Timing of Disclosure and the Size of Innovation

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Abstract

In most industrialized nations, a patent application is made public 18 months after it is filed. The one exception is the United States, which does not publish any information concerning a patent until the patent is granted. Recently, Congress has considered several bills that would change U.S. law to require disclosure of patent applications after 18 months. Opponents of such a change argue that major inventions would be discouraged, as their applications take longer to examine. This paper tests the claim that major inventions take longer to be awarded patents. Using patent citation data, we show that inventions that have longer lags between a patent application and a patent grant are cited more frequently than other patents. We then look at the decision of where to file a patent to see if the secrecy afforded patent applications in the United States is valued by inventors. We conclude that although large inventions will be most affected by the proposed legislative change in disclosure, it is not obvious from the data that the current period of secrecy is valuable to their applicants.

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In practically every industrialized country, patent applications are made public 18 months after the application is filed. This is true whether the patent has been granted or is still in the application process. The one exception is the United States. In the U.S., information on a patent application is not made pubic until the patent is granted. If the patent is never granted, the information is never made public. However, the United States is currently considering changing its laws on patent disclosure to be consistent with the rest of the world. If the change were passed, patent applications would be made public 18 months after the initial application is filed. This paper will analyze the impact of the proposed change on the U.S. patent system.

Proponents of changing the U.S. law on patent application disclosure offer two reasons for their support. One, of course, is that it will make the U.S. laws the same as other nations. The second is that early disclosure will end the practice of "submarine patents." "Submarine patents" are patent applications that drag on for several years and are finally revealed after the technology has been widely adopted. Patent applicants can purposely delay the processing of the application by filing for continuances and divisions of an initial application.[1] After the patent is finally granted, the patent holder can collect royalties from unsuspecting users of the technology. Early disclosure of all patent applications would make "submarine patents" impossible. Opponents of the change argue that it will hurt inventors of monumental inventions. They argue that breakthrough inventions often take a long time to go through the patent process. Opponents of the proposed change fear that the new rules would limit the value of patent protection for these breakthrough inventions (*The Economist*, 1997).

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[1] The most famous example of "submarine patents" are the patents held by Jerome H. Lemelson for robotic equipment for assembly lines. He filed the initial applications in the 1950's, but delayed the process by filing continuances and altering his designs. The patents finally emerged in the 1980's, years after the techniques he patented had been used for years by manufacturers who had no knowledge of his pending applications. Lemelson was able to collect royalties from these manufacturers. (Montgomery, 1998)

Despite the importance of the patent application disclosure issue, very little has been written about it in the economic literature. Aoki and Prusa (1995) present a theoretical model of the effect that the timing of disclosure has on innovation, focusing on the Japanese and American patent systems. They find that, because of disclosure, Japanese inventions should make smaller improvements in quality than do American inventions. However, they also find that Japanese firms should make higher profits than do American firms, as Japanese firms are able to better coordinate their R&D efforts. This is consistent with the sides taken in debate over the proposed changes. Most U.S. firms have come out in support of the proposed changes. In contrast, many small inventors and economists have come out against the proposal because of concerns that the new rules would limit the value of patent protection for breakthrough inventions.

In a model of firms engaged in a patent race, Bloch and Markowitz (1996) show that the length of the delay before potential patents are published has an enormous effect on industrial structure. If the delay is long (for example, in the US), equilibria occur as monopolies if only one firm initially invests in the area or as competition if both firms initially invest. If the delay is short, equilibria involve entry and exit of firms – new firms exiting the sector quickly with disclosure if many firms invested relative to the size of the invention, and firms deliberately lagging slightly behind the leader to enter after disclosure if few firms invested relative to the size of the invention. The American system promotes monopolies in areas with large inventions and competition in areas with smaller inventions. The alternative system of rapid disclosure encourages firms to join the research race for large inventions, and to quit the race for smaller inventions.

In this paper, we use data on United States patents from 1976-1996 to study some of the possible effects of early disclosure. First, we use patent citation data to test the hypothesis that patents that take longer to go through the application process are more significant inventions. We see that such patents are cited more frequently, suggesting that they are indeed more significant. Having shown this, we then ask whether or not inventors value the secrecy offered to patent applications in the United States. We ask where inventors choose to patent inventions by examining evidence of patent families and priority data. If inventors value the secrecy that the United States offers, the United States should be a more attractive priority nation to inventions that expect to take longer going through the application process.

I. The Current Laws on Patent Disclosure

Currently, the United States is the only nation that allows patent applications to remain secret until the patent is granted. Recently, both the U.S. House and Senate have introduced bills to change disclosure rules in the United States.[2] To better understand how such a change might influence innovative activity, we must first discuss the legal implications of such a change.

The date on which a patent application is first filed is its priority date. If the patent is granted, the patent holder is given protection from the priority date onward in all nations for which a patent application is filed within one year of the priority date. As the patent is examined, changes may be made to it. For example, the patent examiner may determine that an application contains too many claims to be considered in a single patent. The applicant is given the choice to

[2] Consideration of legislation to require the publication of patent applications after 18 months began in 1995, when the House introduced the Patent Application Publication Act of 1995 (H.R. 1733). In response, the U.S. Patent Office's proposed regulations to implement early disclosure can be found on the Internet at: http://www.uspto.gov/web/offices/com/hearings/18month/notice/18mopub.html. The bill was not acted upon before the 104th session of Congress ended. In the 105th Congress, both the House and Senate introduced bills to require early publication of patent applications. The House included disclosure of applications after 18 months in the "21st Century Patent System Improvement Act of 1997" (H.R. 400). That same year, the Senate introduced a similar bill, The Omnibus Patent Act of 1997 (S. 507). Again, both bills died before being passed. However, the issue is being revisited in the House in 1999, with the "American Inventors Protection Act of 1999" (H.R. 1907). H.R. 1907 also requires publication of applications after 18 months, but waves the requirement for inventors that agree not to file for patent protection abroad.

abandon the original application and file a new, modified version of the original application. As long as the new application is filed on the same day as the original application is withdrawn, it is labeled a continuation of the original application and given the same priority date as the first application. If the continuation also includes new elements, it is labeled as a "continuation in part." As long as the new claims are substantially related to the original ones, the applicant can keep the original priority date.[3]

Figure 1 gives an example of a patent that has been through several modifications. Note that the application date listed on the front page of the patent, March 13, 1989, is the application date of the most recent version of the application. However, under related application data, we see that this patent is a division and a continuation in part of several earlier patent applications. The earliest related application date (December 30, 1981) would be the priority date for this patent. Protection would be guaranteed from that date, even though the application directly related to this patent wasn't filed until 1989, and the patent wasn't granted until 1991.

The practice of submarine patents comes from taking advantage of the potential modifications that may be made to a patent. The applicant begins by filing a patent with broad claims. Then, a series of continuing applications are filed to keep the patent submerged in the patent office for several years. Once someone produces a product that infringes on the application, the applicant "surfaces" the patent by its issuance. Since protection is guaranteed from the priority date, which comes from the first related patent application, the patent holder can claim infringement on the patent for inventions that occurred since the priority date, even though the inventors of the infringing products were unaware of the pending patent application. (Blount, 1999).

[3] The information in this paragraph comes from Blount (1999) and correspondence with the U.S. Patent Office.

Although submarine patents have received much attention during the debate on early disclosure in Congress, in practice they do not appear to be a significant problem. During testimony to Congress, former U.S. Patent Office Commissioner Bruce Lehman testified that only 627 patents issued from 1971-1993 fit the definition of a submarine patent. Of these, 41% were held by the U.S. government and kept secret for security reasons, and 75 were private patents ordered to be kept secret for security reasons. Thus, only 182 patents, or 0.00028% of the over 2 million patents granted in that time frame, were truly submarine patents. Furthermore, since the Uraguay Round of GATT in 1995, patent protection in the U.S. extends from 20 years from the filing date, as opposed to the previous coverage of 17 years from the date of grant. Thus, indefinitely long submarine patents are no longer possible, even without disclosure of the patent applications. (Blount 1999)

If submarine patents are not a concern, the next question is, as opponents of changing U.S. law argue, whether more significant inventions take longer to go through the patent examination process. We perform two analyses to examine this question. First, we use patent citation data to test the hypothesis that patents that take longer to go through the application process are more significant inventions. Then, we then ask whether or not inventors value the secrecy offered to patent applications in the United States. We do this by examining data on patent families and priority nations.

II. Do Major Innovations Take Longer to go Through the Patent Process?

To begin our analysis of early patent disclosure, we test the hypothesis that more valuable patents take longer to go through the granting process. If this is the case, as opponents of early disclosure argue, mandating publication of patent applications after 18 months may discourage major inventions. To address this question, we will make use of patent citation data from the

United States. When a patent is granted, it contains several citations to earlier patents that are related to the current invention. These citations are analogous to references in a journal article – they tell us the ideas upon which the current patented invention was built. Much research has been done to show that the number of subsequent citations made to a patent is a good measure of the patent's value.[4] Major innovations should be cited more frequently than other inventions. Thus, we will be looking to see whether patents with long grant lags are cited more frequently.

A. Data

For the citation analysis, data on all patents granted in the United States from 1976-1996 were used. After removing patents with clearly erroneous data (such as application dates *after* the grant date), the data sample includes 1,653,992 patents. The main source of the data was a set of CD-ROM's from MicroPatent. These CD's include all of the information available on the front page of a patent, including the date of grant and application. Because disclosure of a patent application would occur 18 months after the first related patent application, we supplemented the MicroPatent data with data on related applications provided by the U.S. Patent Office.[5]

Summary statistics for the lag between patent application and the granting of the patent (the *grant lag*) are given in table 1. Statistics are shown for all patents in the sample, and are also broken down between patents that have U.S. applicants and patents that have foreign applicants. In each case, the mean lag is about 28 months. However, as figure 2 shows, the distributions of grant lags are quite skewed. The median lag ranges from 23 to 24 months. For all patents, the most common grant lag is 20 months. Only 29 percent of patents are granted within 18 months

[4] The relationship between citations and value was first shown by Trajtenberg (1990). Other influential work on patent citations includes research by Adam Jaffe and his co-authors, such as Jaffe, Fogarty, and Banks (1998), Jaffe and Trajtenberg (1996), Caballero and Jaffe (1993), and Jaffe, Henderson, and Trajtenberg (1993).

[5] We thank Jim Hirabayashi for providing the related application data.

of their first related filing. Thus, most patents would lose some secrecy if the requirement to publish all applications within 18 months of filing were adapted.

For the analysis in this paper, we will focus on domestic patent applications – that is, United States patents that have been granted to applicants in the United States. Patent laws vary throughout the world, and the value of patent protection varies as well. Using only domestic patent applications helps ensure that exogenous factors such as the value of patent protection are constant. In addition, foreign applicants of U.S. patents are likely to have filed in their home country first. Because patent applications in other nations are disclosed, they would not benefit from the secrecy that U.S. applicants would. These patents would not be affected by changing the disclosure laws in the United States. There are 930,059 such patents in our data set.

Note from figure 2 that the distribution of grant lags shifts leftward when only domestic patent applicants are considered. The most frequent lag for patents with U.S. applicants is 17 months. About 30 percent of all successful domestic patent applications are granted within 18 months. However, the distribution is highly skewed, as the mean grant lag actually increases slightly. Finally, note that the grant lag varies over time. Figure 3 shows the percentage of all patents granted within 18 months of the first filing. The percentage peaks at 41.8% in 1990, although it was almost as high in the late 1970's. The U-shaped time series is likely explained by the well-documented cutbacks in the patent office budget in 1979 that led to less patents being issued that year.[6]

B. Modeling of Citation Analysis

As stated in the previous section, we focus on citations to all U.S. patents granted to domestic applicants between 1976. However, citations made by both patents with domestic and

[6] See Griliches (1990) for more on the Patent Office budget problems in 1979.

foreign applicants are considered. To analyze patent citations, we use a model developed by Adam Jaffe and his coauthors (Caballero and Jaffe, 1993; Jaffe and Trajtenberg, 1996; Jaffe, Fogarty, and Banks, 1998). The model estimates the likelihood that a patent, *k*, granted in year *t* will be cited by a subsequent patent, *K*, granted in year *T*. An exponential rate of decay and diffusion models the flow of knowledge over time. Thus, the probability can be written as:

(1) $$p(k,K) = \alpha(k,K)\exp[-b_1(T-t)][1-\exp(-b_2(T-t))]$$

where b_1 represents the decay rate, b_2 represents the rate of diffusion, and $\alpha(k,K)$ captures other attributes of both patent *k* and *K* that affect the probability of citation. For example, in this paper we will want to consider the grant lag of the patent as an attribute that may influence the probability of citation. Other factors include the computerization of patent office records, which makes finding related patents easier. As a result, there are more citations made by newer patents. To control for such factors, we include the following parameters in our model:

- the number of months lag between the patent application and grant of the cited patent (g_g)
- the usefulness of the knowledge represented in the patent being cited (α_t), and
- the frequency by which patents granted for in the citing year cite earlier patents (α_T).

Note that the model requires us to estimate attributes associated with the cited year, the citing year, and the lag between them. Because the age of patents enters the model non-linearly, it is possible to identify all three attributes. Although in theory it is possible to estimate such attributes for every citing and cited year, in practice the model does not converge to a solution when it is specified this way. As a result, citing and cited year attributes are grouped into two-year intervals. In addition, it is necessary to normalize one value of each parameter to 1.[7] Using these parameters, the probability of a patent *k* granted in year *t* being cited by a patent, *K*, granted in year *T* can be estimated as:

(2) $$p_{k,K} = g_g a_t a_T \exp[-b_1(T-t)]\{1-\exp[-b_2(T-t)]\} + e_{k,K}.$$

In this paper, the parameter of greatest interest to us is g_k. g_k, tells us the likelihood that a patent with a given grant lag will be cited by subsequent patents. g_{18} is normalized to 1. Thus, estimates of g_g greater than 1 mean patents with that grant lag are more likely to be cited than patents with a grant lag of 18 months, and estimates of g_g less than 1 mean patents with that grant lag are less likely to be cited than patents with a grant lag of 18 months. The null hypothesis for this paper is that g_g will be greater than 1 for patents with a grant lag greater than 18 months.

C. Estimation of the model

Most patents are never cited. Thus, we cannot estimate equation (2) for individual patents, since for most observations the probability is zero. Instead, we group the patents into cohorts of potential citations. For cited patents, the relevant attributes are the year of grant and the lag between application and grant. For citing patents, the relevant attribute is the year of grant. For example, one cohort may be all patents granted in 1976 that have a grant lag of 18 months that are cited by patents granted in 1978. The expected number of citations to a cohort is just the likelihood of a single citation times the number of patents that are potentially cited or citing patents:

(3) $$E[C_{g,t,T}] = (N_{g,t})(N_T) g_g a_t a_T \exp[-b_1(T-t)]\{1-\exp[-b_2(T-t)]\},$$

[7] The normalization is as follows: for cited patents, $a_{1976\text{-}77} = 1$, for citing patents, $a_{1977\text{-}78} = 1$, and for the grant lag, $g_{18} = 1$.

where $C_{g,t,T}$ is the number of citations to the patent cohort of patents granted in year t that have a grant lag of g months made by patents granted in year T, $N_{g,t}$ is the number of patents granted n year t with a grant lag of g (the potentially cited patents), and N_T is the number of patents granted in year T (the potentially citing patents). Defining $p_{g,t,T}$ as the probability that a patent in cohort g,t is cited by a patent in cohort T, equation (3) can be re-written as:

(4) $$p_{t,t,T} = \frac{C_{g,t,T}}{(N_{g,t})(N_T)} = g_g a_t a_T \exp[-b_1(T-t)][1-\exp(-b_2(T-t))] + e_{g,t,T} \,,$$

which can be estimated by non-linear least squares as long as the error term, $e_{g,t,L,T}$ is well-behaved.

Two versions of equation (4) are estimated. First, patents are simply divided into two groups: those with grant lags less than or equal to 18 months and those with grant lags greater than 18 months. Only the second group would be affected by the new law. g is normalized to 1 for patents with grant lags less than or equal to 18 months. The results of this regression are shown in table 2. Results for the year effects and the citing nation are similar to results found by Jaffe and others, except that the citing year effects are insignificant[8]. One result of note is that rising estimates for the year cited effect at the end of the time period, which supports the notion of an upswing in the productivity of R&D during that period[9]. Most importantly, note that patents with grant lags greater than 18 months are 16 percent more likely to be cited than patents with shorter grant lags. This suggests that the patents that would be affected by changing disclosure laws in the United States are more valuable patents.

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[8] A possible explanation for the insignificance of the citing effect is that the current regression does not account for the country of the citing patent, whereas Jaffe's analyses do. Foreign patents cite U.S. patents less frequently than do other U.S. patents, and the percentage of foreign patents has increased over time, thus counteracting increases in the average citations per patent due to computerization of patent office records.

[9] For a discussion on the returns to R&D over time, see Kortum and Lerner (1998) and Popp(1997)

The second regression shows the same result, but in greater detail. It groups all patents with a grant lag of 6 months or less into one group, all patents with a grant lag greater than 5 years into another, and includes separate observations for all grant lags in between (in months). Results of this estimation are given in table 3. The result of most interest of us is the effect of the grant lag on the probability of citation. Recall that the parameter for this effect was normalized to 1 for a grant lag of 18 months. Patents with a longer grant lag are the ones that would lose some secrecy benefits if disclosure were mandated after 18 months. *With only one exception*, patents with a longer grant lag are more likely to be cited than a patent with an 18-month grant lag.[10] Furthermore, *without exception*, patents with a grant lag less than 18 months are less likely to be cited. Except for the parameter for a 17-month grant lag, these estimates are all significantly different from 1 at the 99 percent level.[11] The increasing likelihood of citation is illustrated in figure 4, which plots the g_g parameters against the grant lag in months. The bars represent plus/minus one standard deviation. It does appear that patents that take longer to go through the patent application process are more valuable patents.

III. Is the Privacy of Patent Applications Important to Inventors of Major Innovations?

Having shown that more valuable patents take longer to go through the application process, we now ask whether the secrecy afforded patent applications in the United States is valued by discoverers of major innovations. This second question could be addressed in a number of ways, including direct survey of inventors. Instead, we use evidence on patent families and priority data from patents granted in the United States.

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[10] The exception is for patents with a grant lag greater than 5 years. It is possible that errors in the data may have caused this result, as some patents have very high grant lags.

[11] Because the attribute parameters enter the regression multiplicitively, the null hypothesis of no effect occurs when the parameter equals 1, rather than 0.

A patent family is formed when an applicant protects the same claim (or set of related claims in a single patent document) in several nations. The first nation in which a patent application is submitted is the priority nation, and the date of application there is the priority date for all subsequent family-member applications elsewhere. In order to guarantee protection from the priority date onwards, all family-member applications must be filed within one year of the priority date.

A. Data and Theoretical Considerations

For a major innovation, there will be two distinct incentives pulling the inventor to create a patent family and at the same time to delay a patent family as long as possible. For a large invention, there are more potential monopoly rents to be gained with widespread protection (i.e. a large family). In fact, there is an established literature that uses patent family size as a measure of the value of individual inventions (see Lanjouw *et al*.,1996 for a review).

However, if the secrecy of the application's details is valuable, there will be an incentive to take advantage of the American system's delayed publication regime by using the US as the priority nation and filing other family-member applications close to one year later. Since American applications are not published until they are granted, and other nations publish applications 18 months after receipt, there is an extra period of secrecy to be gained by following this strategy.

The combination of these two effects means that we expect large patents to appreciate the American patent regime as an opportunity to have a large patent family with some degree of planning in the timing of offspring, delaying them until the latest possible date while still ensuring their healthy development. Viewed in that context, our results answer two fundamental questions about the value of secrecy for large inventions:

a) do large inventions have more offspring in their family than small inventions do, and

b) do large inventions value the opportunity to delay those offspring, even if they eventually have more than other inventions do?

As our dataset we use all granted US patents that have a priority date (either in the US or elsewhere) of 1980, 1983, 1985 or 1990, a total of 313,983 documents.[12] Summary statistics of the data are listed in table 4. The data include the number of cites received by each patent within 2 years (early cites), after 2 years (late cites), a dummy variable equal to 1 if the patent is part of a family, a dummy variable equal to 1 if the patent has U.S. priority, and the grant lag. Of that sample, 54 percent list an American applicant. A little more than half of the sample has non-US family members.

We are therefore limiting our attention to patent families with one member granted in the US. This has the disadvantage of omitting from consideration applications that were unsuccessful in the US but may have been successful elsewhere, or families that do not include the US as a member. However, it has the advantage of including only patents of some standard maximum size (i.e. number of claims), since there are well-documented differences between, for example, Japanese patent size at home and their size elsewhere.

B. Estimation of the Model

First, we test the relationship between the importance of an invention and the presence of non-US family members, using

(5) $$Pr(family)=f(year, nation_i, early_i, late_i)$$

where ***year*** is the priority year of the patent,

[12] Data on priority and family members were collected from online access to INPADOC and Derwent patent services provided by the Chemical Abstract Service (CAS).

$nation_i$ is the applicant's nation (a constant term for every patent with applicant nation *i*),

$early_i$ is the number of citations within 2 years of publication (with a coefficient that varies with the applicant nation *i*), and

$late_i$ is the number of citations between 3 and 20 years of publication (again, with a coefficient that varies with the applicant nation *i*).

Separating the effects of early and later citations allows the distinction between inventions that are recognized immediately as large inventions (high early citations) and so may have larger patent families. In contrast, late-bloomers which become large inventions later in their tenure may have applicants who did not recognize the value of their invention a priori and did not apply for protection outside of the US.

Results in Table 5 show that *ceteris paribus*, European and Japanese applicants who protected their inventions in the US are more likely than the average American patent to create a patent family, since their nation-specific constant terms all exceed 1 (the implicit value of the omitted US constant). This result is unsurprising since those applicants have already chosen to pursue protection in a nation other than their home country. However, applicants from other nations whose patents were also granted in the US are significantly *less* likely to apply for protection elsewhere, and Canadians are least likely of all. This is consistent with anecdotal evidence from the Canadian Patent Office which suggests that many Canadian applicants treat the US Patent Office as a substitute for protection in Canada, where Canadians often never protect their inventions at all.

Of more interest are the differences in the effects of subsequent citations on the probability of creating a patent family. For Japanese and American applicants, larger inventions are more likely to have larger families, regardless of when the subsequent citations occur (the coefficients of ***early*** and ***late*** are both positive). However, for each other applicant group, patents which have early citations are less likely to have a family than patents with late citations. This evidence suggests that the speed of knowledge transmission may be a criterion for an applicant in the decision of whether to create a patent family or not. Patents that are quickly or easily absorbed and cited by subsequent patents are less likely to be protected and published outside of the US.

Omitted from the analysis above is explicit consideration of the granting lag for each patent. A lag variable should be significant only if patent applicants anticipate the importance of their patent in advance, and infer the length of the application-to-grant lag they will have to endure. In fact the coefficient on such a variable is positive and significant when included in the regressions above, hinting at a strange result --- that patents with long lags were in fact more apt to apply for families of patents, even when importance is controlled as a separate variable. However, we were also curious to determine whether *all* coefficients differ for patents with longer application-to-grant lags. Our results in Table 6 distinguish between patents with an application lag of 18 months or less, and patents with a lag of longer than 18 months, since it is this latter group which benefit from the application secrecy afforded by the US system.

The coefficients are statistically different for the two groups, with an interesting and somewhat surprising conclusion. The effect of subsequent citation (or patent importance) is everywhere smaller or more negative for patents with a *short* granting lag. That is, a marginal increase in the importance of a patent with a short lag provides little extra encouragement towards starting a family. Instead, the effect of a marginal increase in citations has a more positive effect on a patent that has a long lag, where a decision must be made to sacrifice secrecy for market share. Since short lag patents have lower citations, this result points to an increasing marginal effect of citations on the probability to create a family.

We might therefore reasonably expect that a policy designed to shorten the period of secrecy would create many more patent families. If applicants decide now on the marginal benefits of secrecy versus profits from foreign market shares, a reduction in the legal period of secrecy combined with increasing marginal effects of citations will encourage a dramatic rise in the number of patents protected in multiple nations.

Next, we investigate whether patent families tend to use the US as their priority nation. If large inventions do so, then we know that some element of the US patent regime, perhaps the lag in publication, is valuable to applicants. We test the relationship between the importance of an invention and the presence of non-US family members, using

(6) $$Pr(priority\ in\ US)=f(family,\ year,\ nation_i,\ early_i,\ late_i)$$

where ***family*** is a variable that takes the value of 1 if the patent has a non-US family member,
year is the year of priority for the patent,
$\boldsymbol{nation_i}$ is the applicant's nation (a constant term for every patent with applicant nation i),
$\boldsymbol{early_i}$ is the number of citations within 2 years of publication (with a coefficient that varies with the applicant nation i), and
$\boldsymbol{late_i}$ is the number of citations between 3 and 20 years of publication (again, with a coefficient that varies with the applicant nation i).

In Table 7, we expect that if the timing of information disclosure is important, larger patents should be more eager to obtain priority in the US, and indeed the coefficients of both ***early*** and ***late*** are positive and significant. It is however interesting that the coefficient of ***late*** citations is larger, when the reverse would have been anticipated.

The negative coefficients for each nation are unsurprising when compared to the implicit value of unity for the home nation, since Americans are presumably more inclined to patent in the US than other nations are, strictly through home bias. All other results change very slightly if we consider only non-US applicants for this test.

However, the negative coefficient on ***family*** is very surprising, since it would seem logical for most families of patents to treat the US as their priority nation. This evidence indicates that the secrecy offered by the US patent system may hold great value for large inventions, but is of lesser importance for patent applicants who have already decided to protect their inventions in multiple nations.

Again, we were also curious to determine whether these results differed for patents with different application lags, so Table 8 compares results for patents with lags of 18 months or less to other patents. The results are similar, showing the negative coefficients for families of patents and positive coefficients for citations. However, the effects are much more pronounced for long-lagged patents, in easily explainable directions. Ceteris paribus, patents with a long application-to-grant lag are more likely to use the US as their priority nation, because it offers them secrecy during that long period. Patents with long lags also see much larger effects from early citations and from the presence of a patent family.

This section has shown that there are obvious patterns to the decisions that patent applicants make about families and priority nations. More important or highly cited patents protect themselves in larger families, but the presence of early citations discourages family creation because of disclosure issues. Larger inventions also tend to choose the US as their priority nation. However, in both the family and priority nation decisions, the length of the secrecy period between application and grant has a large effect, suggesting that applicants anticipate the grant lag and modify their behavior accordingly.

IV. Conclusions and policy implications

There has been great concern among inventor's advocacy groups that the proposed change in American patent law would adversely affect inventions, and in particular, pathbreaking inventions. We have used patent data over a twenty-year period to test the hypotheses that important patents take longer to be granted (and therefore would be those most affected by the proposed change in legislation) and that the current period of secrecy is valuable to inventors.

Since only 29 percent of applications in the US have traditionally been granted within 18 months, most patents will have earlier disclosure under the proposed laws. We have found that larger inventions, as measured by subsequent citations, have a longer lag between application and grant. Therefore, large inventions will face earlier disclosure more frequently and by a greater degree than will the average patent.

Larger inventions have a tendency to protect their rights in a family of nations, but with the exception of American and Japanese applicants, have that tendency moderated depending on the speed of citations. The fast transmission of knowledge, as evidenced by early citations, discourages applicants from protecting their rights in a number of nations outside of the US. Larger inventions also tend to obtain US priority, especially if they have a long grant lag and early citations. However, patents with families are actually unexpectedly less likely to obtain US priority in order to safeguard their secrecy as long as possible.

Our conclusion is that while large inventions will be most affected by the proposed legislative change in disclosure, it is not obvious from the data that the current period of secrecy is valuable to their applicants.

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Figure 1 – Sample Patent Application

United States Patent [19]
Michel et al.

[11] **Patent Number:** **5,032,472**
[45] **Date of Patent:** **Jul. 16, 1991**

[54] **FILMS OF CATENATED PHOSPHORUS MATERIALS, THEIR PREPARATION AND USE, AND SEMICONDUCTOR AND OTHER DEVICES EMPLOYING THEM**

[75] Inventors: **Christian G. Michel**, Ossining; **Rozalie Schachter**, New York, both of N.Y.; **Mark A. Kuck**, Upper Montclair, N.J.; **John A. Baumann**, Dobbs Ferry, N.Y.; **Paul M. Raccah**, Chicago, Ill.

[73] Assignee: **Stauffer Chemical Company**, Westport, Conn.

[21] Appl. No.: **322,688**

[22] Filed: **Mar. 13, 1989**

Related U.S. Application Data

[60] Division of Ser. No. 680,367, Dec. 11, 1984, Pat. No. 4,818,636, and a continuation-in-part of Ser. No. 886,587, Jul. 16, 1986, Pat. No. 4,746,500, Ser. No. 796,429, Nov. 8, 1985, Pat. No. 4,732,659, Ser. No. 736,750, May 21, 1985, Pat. No. 4,696,828, Ser. No. 695,255, Jan. 28, 1985, Pat. No. 4,678,266, Ser. No. 695,268, Jan. 28, 1985, abandoned, Ser. No. 619,053, Jun. 11, 1984, Pat. No. 4,558,340, Ser. No. 581,101, Feb. 17, 1984, Pat. No. 4,613,485, Ser. No. 581,102, Feb. 17, 1984, Ser. No. 581,103, Feb. 17, 1984, abandoned, Ser. No. 581,104, Feb. 17, 1984, abandoned, Ser. No. 581,105, Feb. 17, 1984, Pat. No. 4,618,345, Ser. No. 581,115, Feb. 17, 1984, abandoned, Ser. No. 581,139, Feb. 17, 1984, Pat. No. 4,649,024, Ser. No. 581,140, Feb. 17, 1984, abandoned, Ser. No. 581,171, Feb. 17, 1984, abandoned, Ser. No. 509,157, Jun. 29, 1983, abandoned, Ser. No. 509,158, Jun. 29, 1983, Pat. No. 4,591,408, Ser. No. 509,159, Jun. 29, 1983, Pat. No. 4,596,721, Ser. No. 509,175, Jun. 29, 1983, Pat. No. 4,509,066, and Ser. No. 509,210, Jun. 29, 1983, Pat. No. 4,567,503, said Ser. No. 680,367, is a division of Ser. No. 442,208, Nov. 16, 1982, Pat. No. 4,508,931, which is a continuation-in-part of Ser. No. 335,706, Dec. 30, 1981, abandoned, and Ser. No. 419,537, Sep. 17, 1982, Pat. No. 4,620,968, which is a continuation-in-part of Ser. No. 335,706, said Ser. No. 886,587, is a division of Ser. No. 581,101, said Ser. No. 796,429, is a division of Ser. No. 619,053, and a continuation-in-part of Ser. No. 509,175, and Ser. No. 442,208, said Ser. No. 736,750.

[51] **Int. Cl.**[5] **B32B 9/04**
[52] **U.S. Cl.** **428/704**; 428/432; 428/469; 428/472.3; 427/78; 427/109
[58] **Field of Search** 428/704, 432, 469, 472.3

[56] **References Cited**

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4,618,345	10/1986	Tuck et al.	23/293 R
4,649,024	3/1987	Brock et al.	427/82
4,696,828	9/1987	Schachter et al.	427/38

Primary Examiner—George F. Lesmes
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Attorney, Agent, or Firm—F. Eugene Davis, IV

[57] **ABSTRACT**

High phosphorus polyphosphides, namely MP_x, where M is an alkali metal (Li, Na, K, Rb, and Cs) or metals mimicking the bonding behavior of an alkali metal, and x=7 to 15 or very much greater than 15 (new forms of phosphorus) are useful semiconductors in their crystalline, polycrystalline and amorphous forms (boules and films). MP_{15} appears to have the best properties and KP_{15} is the easier to synthesize. P may include other pnictides as well as other trivalent atomic species. Resistance lowering may be accomplished by doping with Ni, Fe, Cr, and other metals having occupied d or f outer electronic levels; or by incorporation of As and other pnictides. Top contacts forming junction devices doped with Ni and employing Ni as a back contact comprise Cu, Al, Mg, Ni, Au, Ag, and Ti. Photovoltaic, photoresistive, and photoluminescent devices are also disclosed. All semiconductor applications appear feasible.

These semiconductors belong to the class of polymer forming, trivalent atomic species forming homatomic, covalent bonds having a coordination number slightly less than 3. The predominant local order appears to be all parallel pentagonal tubes in all forms, including amorphous, except for the monoclinic and twisted fiber allotropes of phosphorus.

(Abstract continued on next page.)

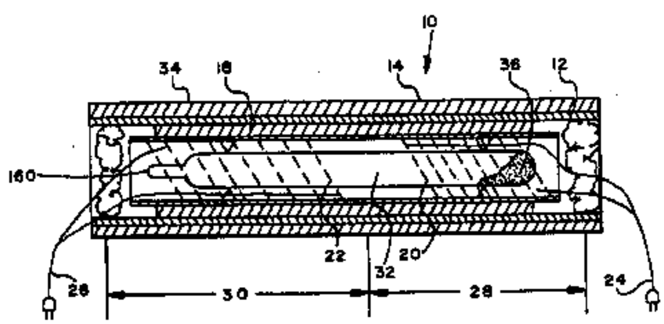


Figure 2 – Distribution of Lags between Application and Grant – All U.S. Patents

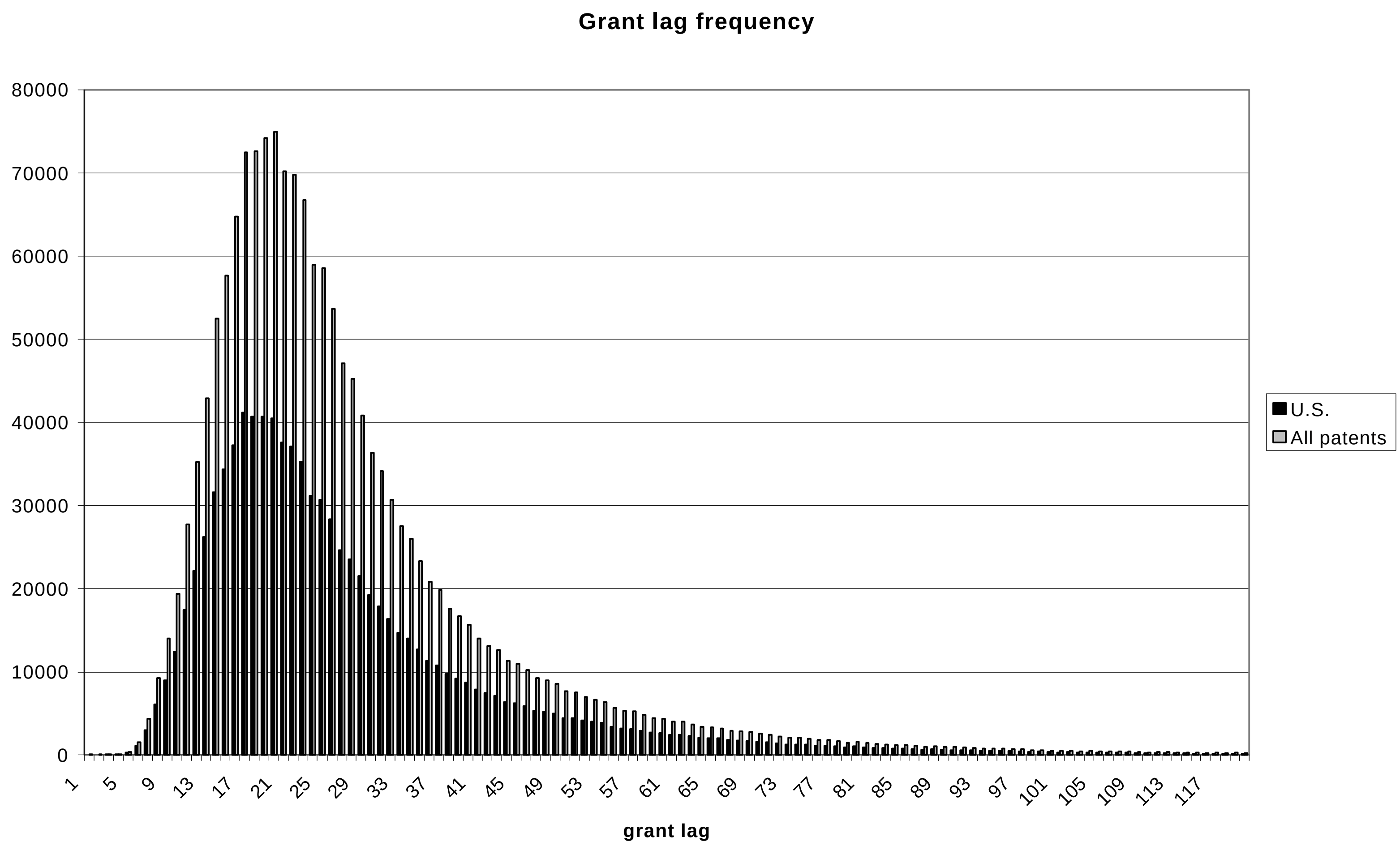
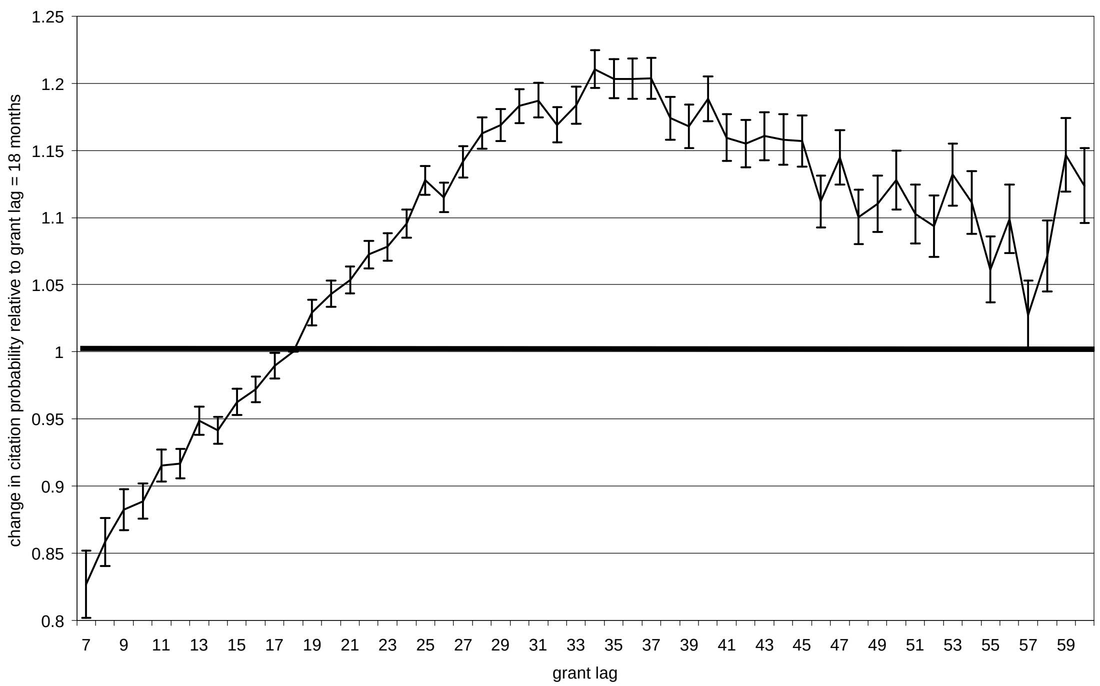


Figure 3 – Percentage of Patents Granted Within 18 months of First Related Application

Figure 4 – Effect of Grant Lag on the Probability of Citation



The figure shows the change in the probability of citation for patents with different grant lags. Grant lags of 18 months are normalized to one. Bars show +/- one standard error.

Table 1 – Summary Statistics for Grant Lags

	All Patents	U.S. Applicants	Foreign Applicants
N	1,653,992	930,059	723,933
mean grant lag (months)	28.34	28.76	27.80
median grant lag (months)	23	23	24
standard deviation of grant lag (months)	18.94	20.70	16.38

Table 2 – Regression Results – Dependent Variable: Probability of Citation

Parameter	**Estimate**	**Standard Error**	**T-ratio (H_0 β=1)**
grant lag > 18 months	1.162	0.0156	10.37
year cited 1978-1979	1.022	0.0318	0.68
year cited 1980-1981	0.977	0.0417	-0.56
year cited 1982-1983	0.979	0.0552	-0.38
year cited 1984-1985	1.001	0.0706	0.02
year cited 1986-1987	1.106	0.0945	1.12
year cited 1988-1989	1.168	0.1179	1.43
year cited 1990-1991	1.214	0.1410	1.52
year cited 1992-1993	1.258	0.1654	1.56
year cited 1994-1996	1.154	0.1726	0.89
year citing 1979-1980	0.920	0.0738	-1.09
year citing 1981-1982	0.883	0.0709	-1.65
year citing 1983-1984	0.840	0.0733	-2.18
year citing 1985-1986	0.837	0.0802	-2.03
year citing 1987-1988	0.863	0.0919	-1.49
year citing 1989-1990	0.893	0.1058	-1.01
year citing 1991-1992	0.864	0.1137	-1.20
year citing 1993-1994	0.897	0.1302	-0.79
year citing 1995-1996	0.955	0.1517	-0.30
decay	0.205	0.0083	24.82*
diffusion	3.83E-06	2.69E-07	14.26*

* -- H_0 is $\beta = 0$

Number of Observations:	420
Summary Statistics	
Degrees of Freedom -- Model	21
Degrees of Freedom -- Error	399
SSE	0.300
MSE	0.0008
Root MSE	0.0274
R-Square	0.8696
Adjusted R-Square	0.8631

Table 3 – Regression Results – Dependent Variable: Probability of Citation

Parameter	Estimate	Standard Error	T-ratio (H_0 β=1)
grant lags 1-6	0.696	0.0312	-9.76
grant lag 7	0.827	0.0250	-6.92
grant lag 8	0.858	0.0181	-7.85
grant lag 9	0.882	0.0152	-7.73
grant lag 10	0.889	0.0133	-8.35
grant lag 11	0.915	0.0119	-7.12
grant lag 12	0.917	0.0109	-7.62
grant lag 13	0.949	0.0105	-4.89
grant lag 14	0.941	0.0099	-5.93
grant lag 15	0.963	0.0097	-3.84
grant lag 16	0.972	0.0096	-2.91
grant lag 17	0.990	0.0094	-1.10
grant lag 18	1.000	N/A	N/A
grant lag 19	1.029	0.0096	3.06
grant lag 20	1.043	0.0097	4.46
grant lag 21	1.054	0.0099	5.40
grant lag 22	1.072	0.0100	7.23
grant lag 23	1.078	0.0102	7.69
grant lag 24	1.096	0.0106	9.04
grant lag 25	1.128	0.0108	11.85
grant lag 26	1.115	0.0109	10.51
grant lag 27	1.142	0.0115	12.34
grant lag 28	1.163	0.0117	13.90
grant lag 29	1.169	0.0120	14.04
grant lag 30	1.183	0.0125	14.61
grant lag 31	1.187	0.0129	14.58
grant lag 32	1.169	0.0131	12.88
grant lag 33	1.184	0.0137	13.42
grant lag 34	1.211	0.0140	15.04
grant lag 35	1.203	0.0145	14.08
grant lag 36	1.203	0.0151	13.49
grant lag 37	1.204	0.0153	13.30
grant lag 38	1.174	0.0159	10.92
grant lag 39	1.168	0.0163	10.32
grant lag 40	1.188	0.0166	11.32
grant lag 41	1.160	0.0173	9.24
grant lag 42	1.155	0.0177	8.79
grant lag 43	1.161	0.0180	8.96
grant lag 44	1.158	0.0188	8.40
grant lag 45	1.157	0.0192	8.20
grant lag 46	1.112	0.0194	5.79
grant lag 47	1.145	0.0205	7.08
grant lag 48	1.101	0.0204	4.93
grant lag 49	1.110	0.0208	5.29
grant lag 50	1.128	0.0221	5.81
grant lag 51	1.103	0.0220	4.68

Table 3 – Regression Results – Dependent Variable: Probability of Citation (continued)

Parameter	Estimate	Standard Error	T-ratio (H_0 β=1)
grant lag 52	1.094	0.0228	4.10
grant lag 53	1.132	0.0231	5.73
grant lag 54	1.111	0.0234	4.76
grant lag 55	1.061	0.0246	2.49
grant lag 56	1.099	0.0255	3.89
grant lag 57	1.027	0.0259	1.06
grant lag 58	1.071	0.0264	2.71
grant lag 59	1.147	0.0275	5.34
grant lag 60	1.124	0.0278	4.46
grant lags 61+	0.982	0.0088	-2.09
year cited 1978-1979	1.019	0.0074	2.55
year cited 1980-1981	0.970	0.0096	-3.16
year cited 1982-1983	0.965	0.0126	-2.76
year cited 1984-1985	0.985	0.0161	-0.93
year cited 1986-1987	1.098	0.0218	4.49
year cited 1988-1989	1.169	0.0273	6.17
year cited 1990-1991	1.218	0.0328	6.64
year cited 1992-1993	1.256	0.0383	6.69
year cited 1994-1996	1.151	0.0399	3.79
year citing 1979-1980	0.920	0.0171	-4.70
year citing 1981-1982	0.882	0.0165	-7.15
year citing 1983-1984	0.840	0.0170	-9.44
year citing 1985-1986	0.836	0.0186	-8.84
year citing 1987-1988	0.862	0.0213	-6.47
year citing 1989-1990	0.891	0.0245	-4.45
year citing 1991-1992	0.861	0.0263	-5.28
year citing 1993-1994	0.895	0.0301	-3.50
year citing 1995-1996	0.953	0.0351	-1.34
decay	0.205	0.0019159	107.03*
diffusion	4.04E-06	7.03E-08	57.51*

* -- H_0 is $\beta = 0$

Number of Observations:	11678

Summary Statistics

Degrees of Freedom -- Model	75
Degrees of Freedom -- Error	11603
SSE	0.4700
MSE	0.00005
Root MSE	0.0064
R-Square	0.8151
Adjusted R-Square	0.8139

Table 4 – Summary Statistics for Patent Families and Priority

Overall Statistics

	mean	st.dev.	min	max
Cites	4.271	5.986	0	280
Early Cites (0-2 yrs)	0.851	1.449	0	43
Late Cites (3+ yrs)	3.421	5.351	0	273
Family (1=yes)	0.513	0.499	0	1
US Priority (1=yes)	0.525	0.499	0	1
Grant Lag (months)	29.198	16.885	0	201

By Application Nation

	Total	US Priority	Family
US	169,940	164,329	57,236
Japan	63,561	81	45,452
Germany	26,631	37	23,404
France	10,125	21	8,927
Britain	9,409	30	7,639
Canada	6,017	130	478
Other Europe	19,545	63	14,729
Other	8,755	70	3,222
Total	313,983	164,761	161,087

By Priority year

	Total	US Priority	Family
1980	66,827	38,349	31,600
1983	69,372	36,365	36,998
1985	77,051	38,792	41,551
1990	100,733	51,255	50,938

Table 5 – Regression Results –Dependent Variable: Probability of Family

Parameter	Estimate	Standard Error	T-ratio*
priority year 1980	-0.652	0.006	102.9
priority year 1983	-0.529	0.006	84.9
priority year 1985	-0.526	0.006	87.9
priority year 1990	-0.529	0.006	100.7
Japanese applicant	1.086	0.008	137.6
German applicant	1.694	0.013	130.8
French applicant	1.743	0.020	85.3
British applicant	1.350	0.019	69.6
Canadian applicant	-0.856	0.030	28.5
Other Eur. applicant	1.240	0.013	97.1
Other applicant	0.208	0.017	11.9
American			
early citations	0.084	0.002	36.5
late citations	0.015	0.001	25.6
Japanese			
early citations	0.010	0.003	2.8
late citations	0.007	0.001	5.4
German			
early citations	-0.017	0.008	2.0
late citations	0.018	0.003	6.5
French			
early citations	-0.024	0.014	1.8
late citations	0.005	0.004	1.1
British			
early citations	-0.020	0.013	1.5
late citations	0.039	0.004	9.1
Canadian			
early citations	-0.010	0.020	0.5
late citations	0.002	0.006	0.4
Other European			
early citations	-0.023	0.009	2.5
late citations	0.006	0.003	2.3
Other nationality			
early citations	-0.059	0.013	4.5
late citations	0.020	0.004	4.5

* -- H_0 is $\beta = 0$

Number of Observations:	313983
Prob correct prediction	0.715
Log likelihood	181112.59

Table 6 – Regression Results – Dependent Variable: Probability of Family

Short application lag (<=18 months)				**Long application lag (>18 months)**		
Parameter	**Estimate**	**Standard Error**	**T-ratio***	**Estimate**	**Standard Error**	**T-ratio***
priority year 1980	-0.707	0.018	38.7	-0.640	0.007	94.0
priority year 1983	-0.609	0.016	37.8	-0.515	0.007	76.0
priority year 1985	-0.663	0.013	50.4	-0.493	0.007	72.9
priority year 1990	-0.704	0.010	67.4	-0.462	0.006	74.9
Japanese applicant	1.137	0.018	62.4	1.067	0.009	121.4
German applicant	1.918	0.29	66.2	1.637	0.015	112.8
French applicant	1.996	0.050	40.1	1.686	0.023	74.9
British applicant	1.454	0.048	30.1	1.323	0.021	62.3
Canadian applicant	-0.873	0.066	13.1	-0.846	0.034	24.9
Other Eur. applicant	1.456	0.029	48.6	1.188	0.014	84.0
Other applicant	-0.052	0.039	1.4	0.289	0.020	14.6
American						
early citations	0.081	0.005	15.2	0.083	0.003	32.5
late citations	0.029	0.002	19.6	0.126	0.001	20.1
Japanese						
early citations	0.008	0.008	1.1	0.009	0.004	2.4
late citations	0.006	0.003	2.0	0.008	0.001	5.9
German						
early citations	-0.021	0.016	1.3	-0.017	0.010	1.7
late citations	0.005	0.009	0.8	0.021	0.003	7.1
French						
early citations	-0.069	0.029	2.4	-0.012	0.016	0.8
late citations	-0.020	0.012	1.6	0.009	0.004	1.9
British						
early citations	-0.056	0.036	1.6	-0.016	0.015	1.1
late citations	0.036	0.012	3.0	0.041	0.005	8.8
Canadian						
early citations	-0.042	0.048	0.9	-0.004	0.022	0.2
late citations	0.016	0.013	1.2	-0.001	0.006	0.0
Other European						
early citations	-0.049	0.022	2.2	-0.019	0.010	1.9
late citations	0.001	0.007	0.2	0.008	0.003	2.8
Other nationality						
early citations	-0.098	0.029	3.4	-0.036	0.015	2.4
late citations	0.024	0.011	2.2	0.018	0.005	3.7

* -- H_0 is $\beta = 0$

Number of Observations:	65430	248553
Prob correct prediction	0.733	0.710
Log likelihood	36476.9	144180.1

Table 7 – Regression Results – Dependent Variable: Probability of US Priority

Parameter	Estimate	Standard Error	T-ratio*
family	-0.598	0.007	80.5
priority year 1980	1.318	0.010	137.7
priority year 1983	1.263	0.010	134.3
priority year 1985	1.262	0.010	138.9
priority year 1990	1.228	0.007	164.0
Japanese applicant	-4.168	0.036	115.2
German applicant	-3.976	0.054	73.1
French applicant	-3.857	0.076	51.0
British applicant	-3.765	0.064	58.5
Canadian applicant	-3.390	0.037	91.4
Other applicant	-3.632	0.045	80.3
Early citations	0.027	0.003	9.2
Late citations	0.032	0.001	34.3

* -- H_0 is $\beta = 0$

Number of Observations:	313983
Prob correct prediction	0.919
Log likelihood	72155.2

Table 8 – Regression Results – Dependent Variable: Probability of US Priority

Short application lag (<=18 months)				**Long application lag (>18 months)**		
Parameter	**Estimate**	**Standard Error**	**T-ratio***	**Estimate**	**Standard Error**	**T-ratio***
family	-0.360	0.016	22.8	-0.702	0.009	81.6
priority year 1980	1.567	0.031	50.5	1.319	0.010	127.8
priority year 1983	1.081	0.024	45.3	1.317	0.010	126.8
priority year 1985	1.142	0.019	59.7	1.308	0.010	125.3
priority year 1990	0.840	0.013	66.2	1.455	0.001	150.3
Japanese applicant	-4.754	0.195	24.4	-4.170	0.037	111.6
German applicant	n/a	n/a	n/a	-3.933	0.056	70.0
French applicant	n/a	n/a	n/a	-3.826	0.078	49.2
British applicant	n/a	n/a	n/a	-3.741	0.066	56.7
Canadian applicant	-4.037	0.171	23.7	-3.366	0.039	86.4
Other applicant	-3.953	0.157	25.2	-3.619	0.048	75.1
Early citations	0.008	0.006	1.3	0.030	0.003	8.9
Late citations	0.041	0.002	16.9	0.033	0.001	32.3

* -- H_0 is $\beta = 0$

Number of Observations:	65430	248553
Prob correct prediction	0.802	0.919
Log likelihood	17147.9	53970.4