

Patent Prosecution and the Timing of Licensing

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1. Introduction and motivation

Licensing of inventions is an essential part of the market for technology. For smaller firms and new enterprises that lack complementary assets and capabilities required to bring new products to market, licensing is an important means of realizing returns on R&D. This is particularly so for non-commercial entities: with very limited options to engage in manufacturing and distribution, to enter into joint ventures, or to be acquired by downstream firms, license agreements are a critical vehicle for technology transfer for these organizations. Many, if not most of these transactions are facilitated by patents. While licensing of intellectual property is certainly possible without patents, as with any form of property uncertainty about the nature of rights being contracted over will increase transactions costs and constrain opportunities for trade. Patents, or, more precisely, patent claims, thus facilitate trade in the market for technology because they define with some precision the technological domain over which licensee and licensor are contracting.

Patents can be expected to facilitate trade in technology in several ways. A patent holder enjoys some protection from the threat of expropriation by a prospective licensee, encouraging greater disclosure of the invention. A patent can also reduce uncertainty about the nature of rights conveyed in a license agreement. The claims of a patent define the economic activities which a licensee can engage in without fear of being sued by the patent holder. Claim language is determined by the process of patent prosecution, involving an independent arbiter (the patent examiner) operating under an objective set of rules and criteria. As compared to contracting between licensor and licensee over a privately defined domain, a patent may therefore provide a definition of the technology being transferred by the license that is more concrete and specific, and more closely aligned with legal processes for enforcement (Haeussler et al., 2014)

Even when granted, and with a presumption of validity, patent rights are still uncertain since they are subject to legal challenge, and re-interpretation in the light of evolving case law. The broader economic impact of this uncertainty is difficult to assess (Lemley and Shapiro, 2005). However an interesting window into the impact of uncertainty around IP rights on the economic value of a patent is provided by the patent prosecution process. Before being granted, a patent application goes through a process of review by the patent office, often involving repeated rounds of interaction between the examiner and the applicant, during the course of which

information is revealed that may progressively reduce uncertainty about the scope of claims that will be eventually granted.

In a novel and interesting 2008 Management Science paper “The Impact of Uncertain Intellectual Property Rights on the Market for Ideas: Evidence from Patent Grant Delays,” Gans, Hsu and Stern (“GHS”) show that the willingness to contract over patent rights is strongly affected by the resolution of uncertainty about patent scope during the examination process. In a sample of patent license agreements made between start-up firms and commercial licensors, GHS show that a large fraction of licenses are entered into prior to the patent being granted, with the probability of entering into an agreement rising sharply following “allowance”—the decision by the examiner that privately communicates to the patentee the nature of the claims that will make it into the issued patent.¹ The authors propose that allowance is the point at which uncertainties about scope and content of the patent are mostly resolved.² According to GHS, once the application reaches allowance, property rights are less uncertain and reduce the potential for expropriation, thus enabling more detailed knowledge disclosure by the licensor and, as a result, market exchange of technology.

The GHS paper’s findings are consistent with some theoretical considerations about the expected impact of uncertainty in markets for technology. Without an unambiguous definition of the scope of the technology being transacted over, self-interested licensors can be expected to misrepresent the nature of the rights they are selling and self-interested licensees would be expected to be wary of such misrepresentations, leading to market failure (Arrow, 1962; Akerlof, 1970)). Even if there was complete and verifiable disclosure between the parties, until the patent office makes its final decision neither party can be certain of the scope of IP rights that the patent office would grant them. While parties may be able to contract around this problem to some degree by negotiating contingent terms, the additional complexity of writing these agreements (which are necessarily incomplete) may be costly enough that the licensor and licensee prefer to wait until uncertainty has been sufficiently resolved.

¹ The timeline of a patent application proceeds from filing, to initial office action, applicant’s response, potential further office actions and responses, to allowance, and then to issuance.

² Note that IPRs are never completely certain until the highest court has spoken (Lemley and Shapiro, 2005)

GHS test the proposition that patent allowance increases the hazard of patent licensing using a sample of 198 patents for which licensing agreements were disclosed in the SDC platinum database. The license agreements were all reached between 1990 and 1999. This sample is thus selected both on successful licensing, and on the licenses having been publicly disclosed. By conditioning on the time elapsed between patent filing and patent allowance, *the allowance lag* (a proxy measure of the value, novelty, or scope of the invention, if “bigger” patents take longer to examine), GHS argue that they estimate the causal effect that allowance has on patent licensing. They further explore how firm characteristics and the property rights environment impact the timing of licensing. Their results show that in environments in which there are alternative channels to prevent expropriation, such as strong social networks in which reputation is important, the importance of patent allowance on the hazard of licensing is diminished.

A more recent paper by Hegde and Luo (2016) supports GHS’s findings and conclusions, providing evidence that the public disclosure of patent applications after the 1999 American Inventors Protection Act resulted in a higher rate of pre-grant licensing—and that the hazard of licensing was significantly higher immediately following publication of a patent application.

In this paper, we start by replicating GHS using a new sample of patents granted to two major academic medical centers. This is a somewhat different context than the commercial licenses in the GHS sample, but these data have the two feature that allow us to avoid the potential problems of the GHS sample. First, in these data the history of each patent begins when its inventors submit a “Disclosure” to their institution’s technology licensing office (“TLO”), and we are therefore able to track the licensing history of the patent beginning prior to the filing of patent application through to licensing or expiration/non-renewal. Unlike the left-censored sample used by GHS, we observe any licensing that takes place prior to filing a patent application, and are also able to estimate the impact of filing an application on the hazard of licensing, not just the impact of post-application events.

In this different context, the methodology used by GHS gives results that are opposite to their findings: contrary to GHS we find that it is patent filing and patent issuance that trigger licensing rather than the allowance of claims by the examiner.³

2. Data sources and methods

The data for this paper come from the technology licensing offices of two of the most innovative academic medical centers in the world with over \$1.4 billion in research funding for 2012. From the archival records of these TLOs we track the history of 396 patents from first “disclosure” of the invention to the TLO by the inventor, through the filing of a patent application, the stages of patent prosecution including allowance, issuance of the patent, and then either execution of a license or expiration of the patent upon reaching full term or from non-payment of renewal fees. These 396 patents were filed and granted between 1980 and 2008, and were selected from a larger sample of more than 685 patents for having an “uncomplicated” prosecution history free of continuations, divisionals and continuations-in-part. License status was observed through February 2011, which means that the elapsed time between first disclosure to the TLO and licensing is censored for over half of these patents.

In addition to information on the timing of licensing we also use USPTO “front page” data to characterize each patent, including patent classes, number of claims, forward and backward citations as well as non-patent literature citations. Our measure of forward citations is scaled by the number of years during which the patent was at risk of being cited to (partially) account for censoring of citations. All of the patents are exclusively in the life sciences and medical device industries. Thus while GHS control for sectoral differences using industry fixed effects, here we control for the types of technology in our sample. Using the main USPTO patent classes (and in some cases, visual inspection of the text of the patent) we assign each of our patents into six technology class groups: Molecular Biology, Chemistry, Drugs, Surgery, Electrical and Electronic, Optical. Fixed effects for these groups control for factors such as the nature of potential licensees, and different technology development profiles or target end-user markets.

³ A study by Jeong and Lee (2012) also attempted to replicate the GHS study using a sample of patents obtained by South Korean public research organizations. This paper also failed to reproduce GHS’ findings, but few of the reported results can be directly compared to the GHS paper, and their models omit many important controls.

For example, we expect that molecular biology patents will be licensed largely by biopharmaceutical companies facing a long development timeline. On the other hand, the patents in our Optical class group will likely be licensed by medical device companies specialized in imaging and subject to a shorter development cycle. Based on careful reading of the patent disclosure, we further create a dummy variable that identifies whether the invention is a medical device: as compared to drugs medical devices have a very different FDA approval process and as a result a different time to market.

3. Descriptive Statistics

Of the sample of 396 patents, 160 (40%) were licensed during the period in which we observe them. Of the remaining 236 unlicensed patents, 56% (133) were right-censored in 2011, 37% (87) were not renewed when their maintenance fees were due (22 at the first renewal date four years after issuance, 41 at the second renewal eight years after issuance, 24 at the third renewal twelve years after issuance) and the remaining 16 patents expired unlicensed at term.

We observe all of these patents from the date on which the invention was disclosed to the TLO by the inventors. Notably none are licensed before patent protection is sought through filing of an application at the USPTO. Once filed, about half of the 160 licensed patents were licensed before allowance, eight during the time period between allowance and issue and the remaining 72 after issuance.

Table 1 gives the mean values of the patent characteristics by license status, with a t-test of means between the two groups. We caution that these statistics do not control for censoring of license status. The “unlicensed” group of patents contains both patents that expired unlicensed, and patents that might still be licensed after the end of the observation period. Not surprisingly, given the right-censoring of duration until licensing, the licensed patents in the sample are from earlier cohorts than unlicensed patents. Note also that the patents in our sample are on average quite recent, with the majority filed in the 1990s and early 2000s. This reflects the fact that patenting has become a more important activity for our two institutions and for universities in general over our observation window (Lach and Schankerman, 2004; Belenzon and Schankerman, 2007; Link et al., 2008.)

We observe that on average our licensed patents are highly cited and significantly more so than our unlicensed patents averaging 1.64 vs 0.79 forward cites per year. This indicates that success in markets for technologies is significantly correlated with forward cites, which have previously been shown to indicate patent importance or value (Trajtenberg (1990), Harhoff et al. (1999)).

On average, the licensed patents in our sample also have higher numbers of backwards citations to previously granted patents, implying that they are building on more established science and technology. In addition, they cite slightly older prior patents than the unlicensed group, but the difference between the two groups is not statistically significant. Similarly, our licensed patents have a larger number of non-patent cites than the non-licensed group.

One might conclude from the above observations that our licensed patents are more “basic” in the sense of Jaffe, Henderson, and Trajtenberg (1993). However t-tests of means across different technology class groups do not show significantly more licensed patents in the groups corresponding to more basic (i.e. closer to science rather than engineering) fields such as molecular biology or drugs. The distribution of patents across technology class-groups is broadly similar for licensed versus unlicensed patents. The sample as a whole is dominated by drug and molecular biology patents (with about 30% in drugs, 18% in molecular biology and 10% in chemistry). The only class group with significantly different means between licensed and unlicensed patents is electrical and electronic. Only 1.9% of licensed patents but 6.4% of unlicensed patents belong to this field.

Finally, these univariate comparisons show that licensed patents have greater scope as proxied either by the number of claims, or the number of unique 4-digit IPC codes, than unlicensed patents. This is consistent with previous literature that shows that patent scope measured this way is significantly correlated with patent value and willingness to invest in further development (Lerner, 1994).

Figures 1-3 plot the Kaplan-Meier failure function (the cumulative fraction of patents licensed over time, controlling for censoring) for different subgroups in the data. In univariate comparisons, these charts show significant differences in the hazard of licensing between patents with forward cites above the median and those with forward cites below the median, and across

different technology classes. Note though that there is no discernable difference between patents with above- or below-median number of unique 4-digit IPC codes.

Table 2 shows summary statistics for the duration of some of the different episodes we observe over the life of each patent: the time elapsed from TLO disclosure of the invention to filing of a patent application with the USPTO; time elapsed from filing the application to the allowance of the patent; and the time elapsed from TLO disclosure to licensing (if any). We observe that on average it took 30 months from USPTO patent filing to allowance for all 396 patents in our sample and 53 months from disclosure to licensing for the 160 licensed patents in our sample. Interestingly, we find that on average, patents that are licensed have a significantly longer allowance lag: 33 months versus 29 months of the patents for which we do not observe a license.⁴

Figure 4 shows a frequency distribution of the time to licensing of the licensed patents in our sample (the “licensing lag”). We observe that the majority of the patents are licensed within 4 years of disclosure, but the distribution has a long tail with some patents licensed close to the end of their term.

Figure 5 shows the baseline hazard from a flexible piecewise exponential model, with no covariates. Peaks in the hazard function at the time of patent filing and at the average time until issuance, rather than at the average time until allowance, suggest that the core GHS result may not hold in these data.

Figure 6 plots the Kaplan-Meier failure function for three different samples of patents in our data: (1) a sample containing only the 160 patents that were licensed during the observation period, (2) a sample that also includes 103 additional patents that expired unlicensed, and (3) a sample that also includes another 133 patents which were still in force by the end of the observation period, but for which license status was censored. Differences between these curves presage the variation in results we obtain below in estimating models of the hazard of licensing using different samples.

⁴ Obviously, this comparison is affected by right-censoring of license status.

4. Analysis and results.

We follow GHS and estimate Cox survival models for time-until-licensing. The Cox model requires no assumption on the functional form for the baseline hazard, but requires “proportional hazards” in the sense of a constant relative hazard between strata defined by different values of covariates.⁵ Using the semi-parametric Cox model allows us to replicate GHS most closely, however we also estimate the parametric Weibull survival model, which imposes a monotonic baseline hazard. A decreasing baseline hazard is consistent with patents becoming less and less valuable to potential licensees as they get closer to expiration, all else equal, and thus less likely to be licensed as time goes past. (See Cockburn, Lanjouw, and Schankerman (2016) for a simple model that incorporates this feature.) Following GHS as closely as possible, we control for application year fixed effects and stratify by technology patent class group. The impact of a patent allowance is captured by a time-varying indicator variable that turns “on” following allowance of the patent and stays “on” until the patent is no longer at risk of licensing, with a similarly constructed variable used to capture the effect of issuance. Following GHS, we further control for unobserved patent “quality” by conditioning on the time from patent application to patent allowances—the “allowance lag.” This may mitigate any endogeneity problem induced by unobserved quality being correlated with the time-until-license.

Table 3 presents results from attempting to replicate the findings of GHS. The models in the first three columns correspond to GHS’s Table 2: Cox models for time-until-licensing are estimated using only the licensed patents in our sample with no controls for patent characteristics. Time at risk of licensing starts at the patent application date.

Contrary to GHS, we find that patent allowance does not significantly increase the hazard of licensing for our sample of patents, once we control for issuance. In model (1) the hazard of licensing is estimated to be 44% higher after allowance (for comparison, GHS estimated a highly significant hazard ratio of 3.241.) In model (2) the effect of allowance is still positive after controlling for the allowance lag and technology class and application year effects, though only marginally significant. But in our models the allowance lag has no effect on the hazard of licensing, whereas GHS found a negative and significant effect. Note also that the coefficient on

⁵ Tests for proportional hazards using Schoenfeld residuals suggest that our data do not violate the constant relative hazards assumption.

allowance is essentially unchanged, while GHS found that controlling for allowance lag substantially reduced the size of the estimated effect of allowance. The most substantive departure from GHS is in model (3), where we find that patent issuance has a large and significant effect, increasing the hazard of licensing five-fold, while allowance and allowance lag have no effect. (The coefficient on allowance switches sign, but cannot be statistically distinguished from zero.) In the equivalent model estimated by GHS opposite results were obtained: if anything issuance decreased the hazard of licensing, even though the effect was statistically insignificant, while the estimated effect of allowance was essentially unchanged.

In models (4) and (5) we re-estimate the model (3) regression, but expand the sample to include patents for which we do not observe a license. In model (4) we add those patents that remain unlicensed through to expiration or non-renewal. In model (5) we add all unlicensed patents (both censored and expired/abandoned). Not surprisingly, once we add patents for which we observe their full history, but which were not licensed prior to expiration, the estimated effect of issuance falls substantially. Further expanding the sample to include patents for which the license status was censored causes the issuance effect to lose significance though its magnitude is largely unchanged. In these two regressions the allowance lag now has a positive and significant effect on the hazard of licensing, implying that those patents that took longer in the examination process had a somewhat higher hazard of licensing. In contrast, GHS estimated a negative and significant coefficient on allowance lag.

Table 4 presents results from trying to reproduce the findings of GHS with the additional covariates included (similar to GHS Table 3). As before, we control for application year fixed effects and the model is stratified by technology class groups. (GHS also have region controls, but all our patents originate in the same region.)

Our estimated effects again deviate from the GHS results. Using the Cox Proportional Hazards model, we find that for these patents, it is issuance rather than allowance that increases the hazard of licensing. The estimated effects are consistent with our earlier models without patent characteristics covariates. In fact, when issuance is included, the allowance effect becomes negative albeit insignificant. Puzzlingly, none of the additional covariates have a significant impact on the hazard of licensing. As a robustness check, we also present estimates

from parametric Weibull models.⁶ In the Weibull models, the estimated effects are quite similar to those obtained in the Cox models: we again find that while allowance appears to significantly increase the hazard of licensing, the estimated coefficient loses statistical significance and switches sign when we also include the patent issuance variable which, as before, has a very large and positive effect on the hazard of licensing. (Other parametric models, such as lognormal or log-logistic, which impose a non-monotonic rising-then-falling baseline hazard fit the data less well.) Allowance lag is again insignificant in all of the models. Note that none of the patent characteristics variables such as forward and backward cites or scope indicators have a statistically distinguishable effect. (In similar models estimated by GHS on their sample, the number of patent classes was associated with higher hazard of licensing while patents that cited older prior art were at a lower hazard of licensing.)

Table 5 shows the impact of constructing the sample conditional on successful licensing. All regressions use a Cox Proportional Hazards specification with year fixed effects and stratification on technology class groups, and additional patent characteristics covariates as in Table 4. In models (1) and (2) of Table 5 we begin with estimates for the sample of patents which were licensed prior to the end of our observation period, as in GHS. (These repeat the results from Table 4.) Models (3) and (4) are the same regression specifications, but the sample consists of all patents for which we observe the entire history through to expiration or nonrenewal, i.e. both licensed and unlicensed patents, with no censoring of license status. Models (5) and (6) further expand the sample to include patents for which license status was right-censored: they were at risk for licensing during the period of observation but remained unlicensed (but active and available to be licensed) through the end of our observation period in 2011. Once we no longer condition on successful licensing, we again find that the magnitude of the effect of patent issuance falls substantially. Interestingly, in these larger samples, some of the patent characteristics covariates, such as forward cites per year, and patent scope, as measured by the number of unique four digit IPCs, now have positive and significant effects on the hazard of licensing. While these covariates had no discernable effect on the hazard of licensing for licensed patents, they appear to have some ability to distinguish between licensed and unlicensed patents.

⁶ The estimated ancillary parameter implies a baseline hazard that decreases over time.

Put another way, sampling on success subsumes any effect of cross-sectional variation in patent “quality.”

In Table 6, we use the absence of left-censoring of licensing history in our data to further explore the relationship between resolution of uncertainty and licensing. Recall that since we observe this set of inventions from the time they were disclosed to the technology licensing office, rather than from the time that the patent was filed, we are able to estimate models where the time at risk for licensing starts from invention disclosure. One question we are interested in is whether it is the post-filing resolution of uncertainty through allowance or issuance that is the primary trigger of licensing, or whether this effect is dominated by the effect of the licensor’s decision to file for patent protection. Put another way, does left-censoring the time-until-license have an effect on the estimated effect of allowance or issuance?

Table 6 shows results from estimating models using the sample of patents for which license status is uncensored. However models (1) and (2), unlike those in Table 5, allow inventions to be at risk of licensing starting from the date that they were first disclosed to TLO. Model (1) shows that patent filing has a very large and positive impact on the hazard of licensing, and appears to “knock out” the effect of issuance. The coefficient on issuance falls sharply (hazard ratio falls from 2.7 in the equivalent regression in Table 5 column (4) to 1.76) and completely loses statistical significance. The incremental effect of post-filing resolution of uncertainty over the initial legal “crystallization” of the invention in the form of a patent application thus appears to be small—or at least difficult to statistically distinguish in this sample. Another way to see this is to look at the impact on the estimated issuance effect just from expanding the period of time over which each patent is observed. Model (2) uses the same sample as model (1), but drops the filing variable. Little impact is seen on the estimated coefficients on the other variables: issuance is still insignificant. Only when the sample is left-censored, effectively subsuming the effect of patent filing into the baseline hazard, does the issuance effect become statistically significant. See model (3) in this table which shows the same regression but with left-censoring of time-until-licensing (repeating the estimates from Table 5, model (4)).

5. Conclusion and Discussion

Contrary to GHS, we find that it is the act of filing a patent application, or the final issuance of a granted patent, that has the largest impact on the hazard of licensing, rather than the “intermediate” resolution of uncertainty associated with allowance by the patent examiner. Our results are robust to including controls for various characteristics of patents such as forward citations, and to different parametric assumptions about the data-generating process.

Our failure to reproduce the findings of GHS is intriguing—we did not merely find a null result, with insignificant effects. Rather we obtained strongly significant results that are the opposite of what GHS found. This does not necessarily contradict the core message of GHS—that the timing of transactions in the market for technology is affected by uncertainty in the scope of the rights being transacted over—but our findings here suggest that their emphasis on the revelation of information at intermediate stages of the patent prosecution process may be misplaced.

Reasons for the divergence between our results and those of GHS remain a topic of continued investigation. Limitations of publically accessible data on licensing may be one factor. GHS were constrained to look only at successfully licensed patents, and only at the period following filing of the patent application. Within our data, “sampling on success” does appear to have a large impact on estimated effects, as does left-censoring of the history of these inventions.

But it is also important to recognize that the data used in this study differs from GHS in important respects. It may be that our sample is informative only about the behavior of two idiosyncratic licensors, versus the much larger number of firms (though fewer total patents) in GHS. We note that as academic institutions, they may have quite different licensing policies than for-profit entities, and may interact quite differently with potential licensees. Academic TLOs typically pursue the goal of rapid and extensive technology transfer in addition to that of maximization of licensing revenues. As pointed out above, these entities have no realistic ability to internally exploit these inventions as an alternative to licensing and may therefore be forced to license on terms that are much more favorable to licensees than those reached in the commercial negotiations underlying the GHS data, bringing more licensees to the table and/or reaching agreement on terms more quickly. Relative to for-profit licensors, they may also disclose

information about an invention much more rapidly (for example via a “paired” academic paper (Murray and Stern, 2007) prompting much earlier interest among licensees, with the result that licensing takes place promptly after the patent application is filed.

Motivations of the licensors in the GHS sample are unclear, but it seems likely that the agreements they collected reflect a combination of both “opportunity licensing” (where the licensor is trying to stimulate use of its technology, or approaching potential licenses cooperatively (Teece, 1988; Gans and Stern, 2003) and “enforcement licensing” (where the licensor has an active program to identify infringers and capture license revenue through the threat of litigation.) These motivations may result in quite different timing of licensing versus academic licensors, independent of any effect of resolution of uncertainty as to the scope of the patent. It is also possible that prospective licensees view academic licensors as being less likely to engage in misrepresentation of the nature of the rights being offered or otherwise behave opportunistically. A further difference between our sample of patents and that of GHS is that these are academic inventions, and therefore potentially substantially more “basic” in the sense of being further away from commercialization.

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Table 1: T-Test of Means between Licensed and Unlicensed Patents

	Unlicensed Patents Means	Licensed Patents Means	P value, Two Sided T-test	T-value
Year of TLO disclosure	1995.42	1993.94	0.015	2.45
Year of Filing	1995.93	1994.53	0.020	2.34
Allowance Year	1998.88	1997.64	0.068	1.83
Issue Year	1999.42	1998.29	0.095	1.68
Allowance Lag (Months)	28.84	33.01	0.024	-2.26
Forward Cites per Year	0.79	1.64	0.000	-4.75
Number of Backward Cites	8.31	12.71	0.005	-2.82
Number of Unique 4-digit IPCs	2.07	2.48	0.006	-2.76
Non Patent Literature Cites	18.23	22.61	0.078	-1.77
Mean Age of Backward Citations	8.96	9.66	0.197	-1.29
Number of Claims	17.78	20.93	0.046	-2.00
Device	0.19	0.25	0.225	1.22
Technology Class: Molecular Biology	0.23	0.19	0.279	-1.08
Technology Class: Chemistry	0.11	0.11	0.943	-0.07
Technology Class: Drugs	0.29	0.30	0.951	0.06
Technology Class: Surgery	0.24	0.23	0.732	-0.34
Technology Class: Electricity and Electronics	0.02	0.06	0.036	2.11
Technology Class: Optics	0.04	0.04	0.781	-0.28
Number of Observations	236	160		

Table 2: Summary Statistics of Lags (in months)

	Number of Observations	Mean	Std. Dev.	Min	Max
File Lag (TLO Disclosure to Filing)	396	6.68	6.16	0.07	37.42
Allowance Lag (Filing to Allowance)	396	30.53	18.07	3	122
Issue Lag (Allowance to Issue)	396	7.04	4.53	2.30	35.61
License Lag (TLO Disclosure to Licensing)	160	53.54	42.75	4	259

Figure 1: Kaplan-Meier Failure Functions by Main Class Groups. Sample includes all patents.

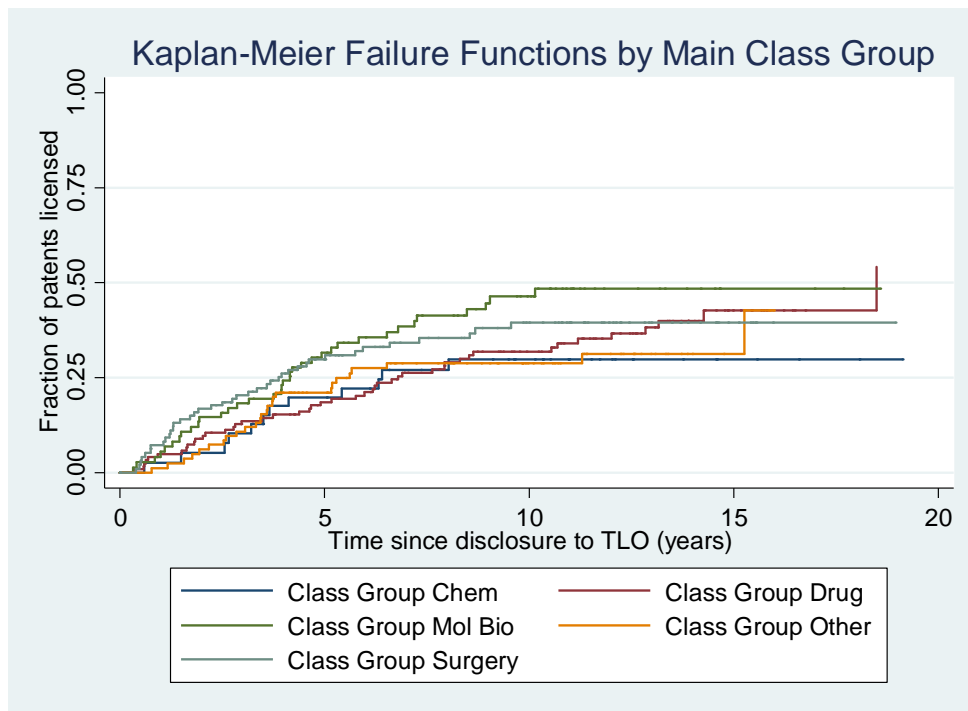


Figure 2: Kaplan-Meier Failure Functions for above and below Median Forward Cites per Year. Sample includes all patents.

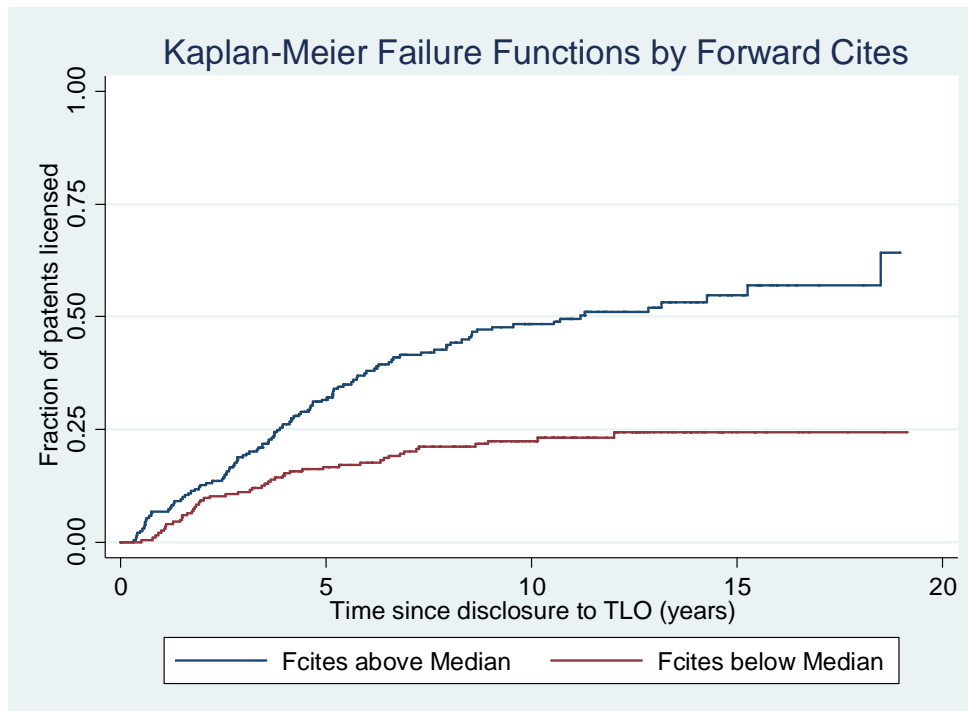


Figure 3: Kaplan-Meier Failure Functions for above and below Median Number of Unique 4-digit IPC codes. Sample includes all patents.

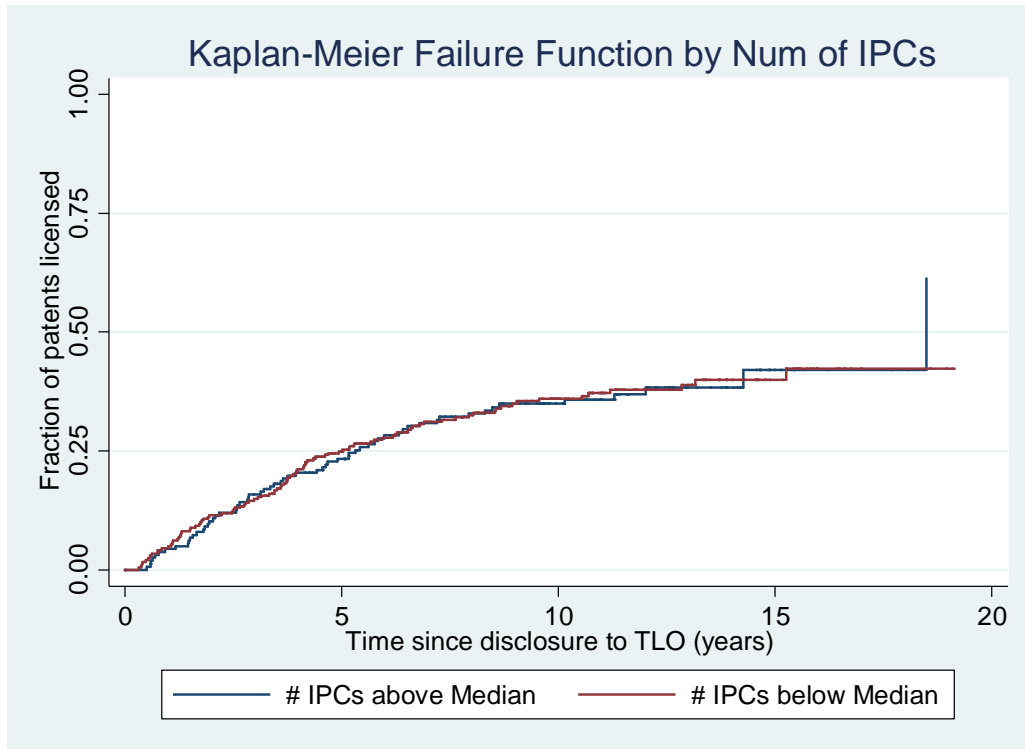


Figure 4: Frequency Distribution of Time to Licensing in Months. Licensed Patents Only.

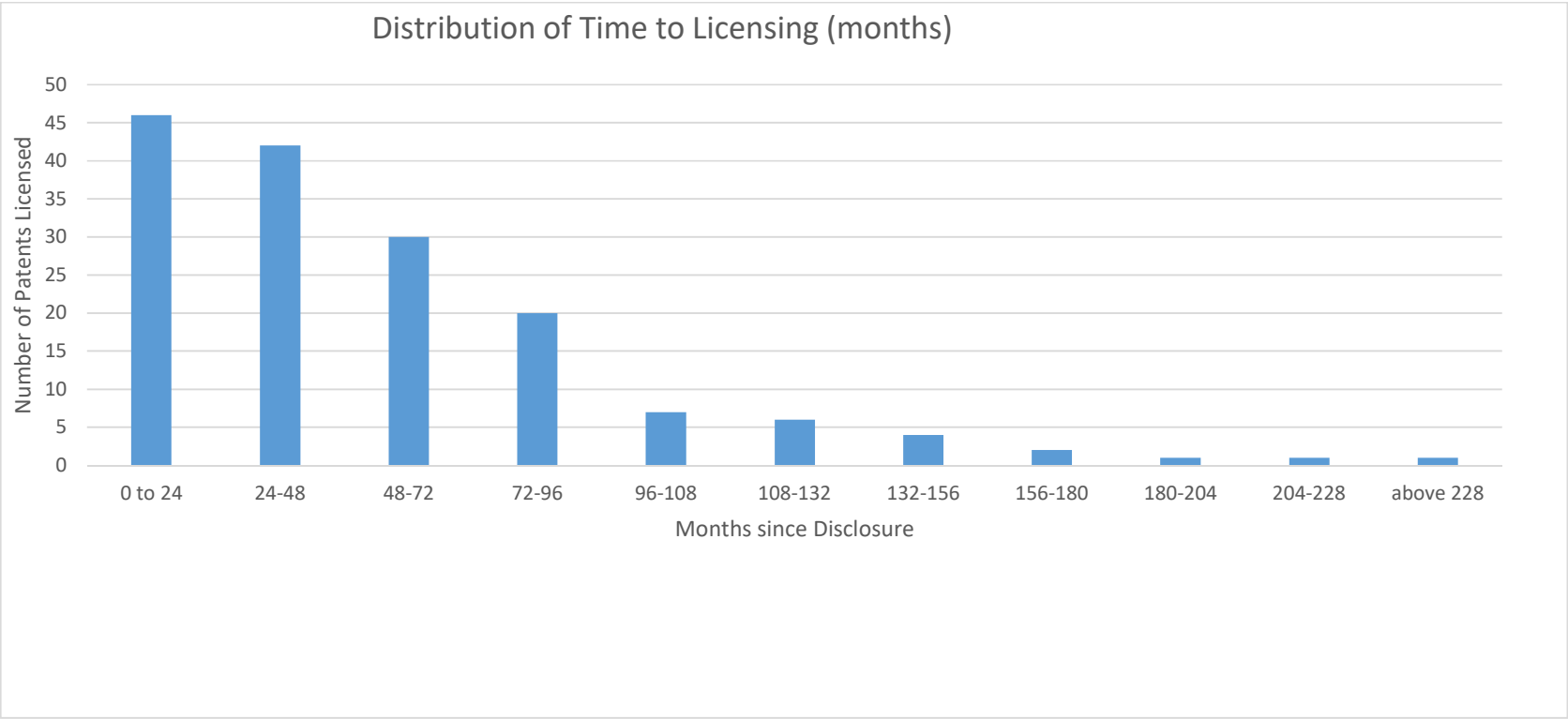


Figure 5: Baseline Hazard of Licensing from a Flexible Piecewise Exponential Model. Sample Includes All Patents

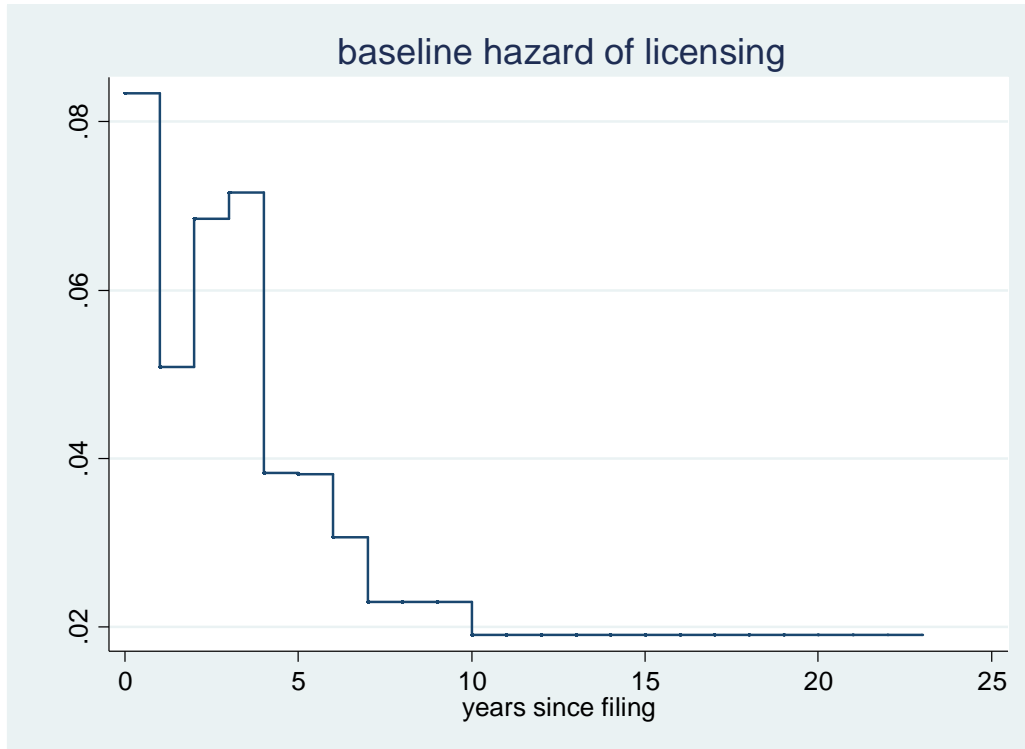


Figure 6. Fraction of Patents Licensed based on the Kaplan-Meier Estimates of the Failure Function at yearly intervals since Invention Disclosure to TLO

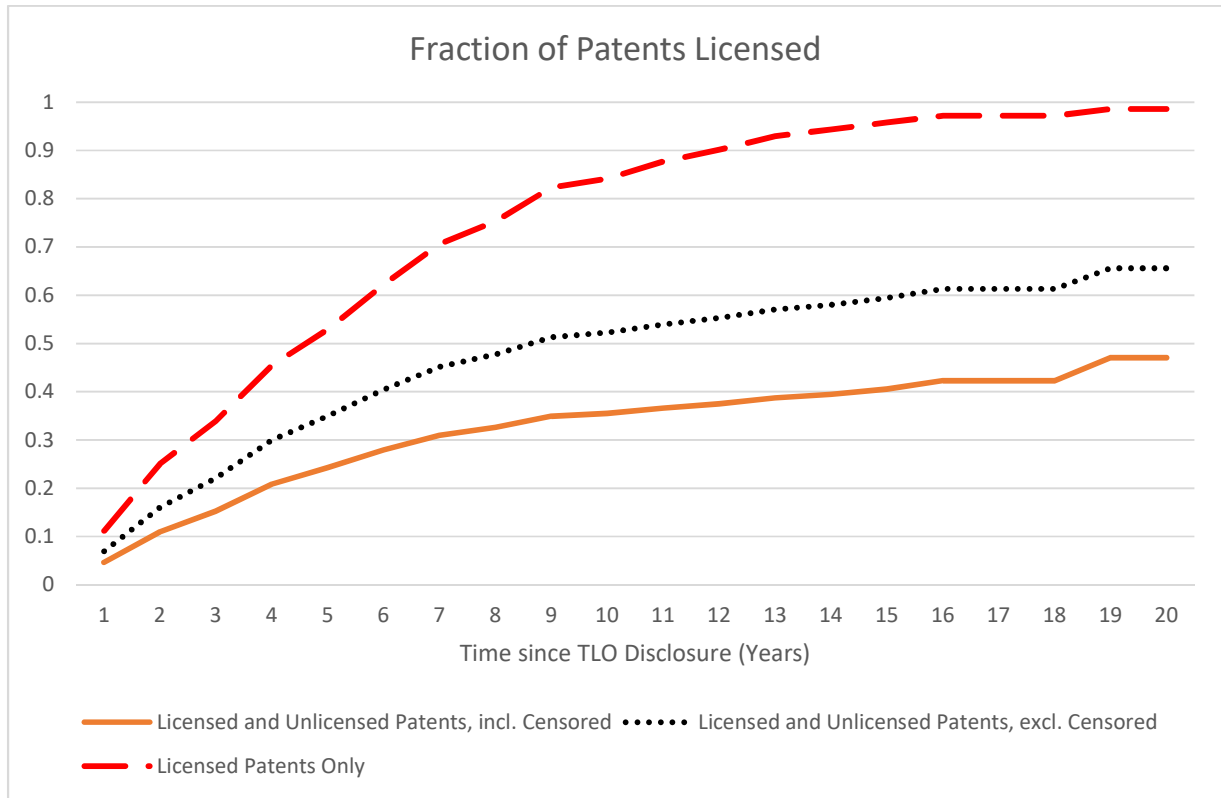


Table 3: Cox Proportional Hazards Models

Time at risk starts at patent filing. Hazard Ratios Reported.

	(1)	(2)	(3)	(4)	(5)
Time at Risk Starts at Disclosure	USPTO	USPTO	USPTO	USPTO	USPTO
Sample of patents	Licensed Only	Licensed Only	Licensed Only	Licensed and Unlicensed (excl. censored)	Licensed and Unlicensed (incl. censored)
Allowed	1.439** (0.258)	1.600* (0.427)	0.678 (0.304)	0.756 (0.332)	0.607 (0.263)
Allowance Lag		0.995 (0.003)	1.001 (0.003)	1.010*** (0.004)	1.009** (0.004)
Issued			5.212*** (2.180)	2.444** (1.021)	1.925 (0.794)
Application Year FE		YES	YES	YES	YES
Class Group Strata		YES	YES	YES	YES
Observations	701	701	701	1,139	1,771

Robust Standard Errors in Parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Survival Models with Patent Covariates

Time at risk starts at patent filing. Sample includes only licensed patents. Hazard Ratios

	(1)	(2)	(3)	(4)
Sample of patents	Licensed Only	Licensed Only	Licensed Only	Licensed Only
Time at Risk Starts at Disclosure to:	USPTO	USPTO	USPTO	USPTO
Model	COX	COX	WEIBULL	WEIBULL
Allowed	1.607*	0.668	1.928***	0.652
	(0.432)	(0.304)	(0.428)	(0.259)
Allowance Lag	0.994*	1.000	0.997	1.003
	(0.004)	(0.004)	(0.003)	(0.003)
Issued		5.334***		6.851***
		(2.299)		(2.709)
Forward Cites per Year	1.029	1.020	1.010	1.008
	(0.026)	(0.034)	(0.021)	(0.032)
Number of Cited Patents	1.000	1.004	1.000	1.002
	(0.004)	(0.004)	(0.003)	(0.004)
Device	1.217	1.119	1.157	1.108
	(0.261)	(0.283)	(0.180)	(0.240)
Number of Unique 4-Digit IPCs	1.026	1.006	1.020	1.003
	(0.036)	(0.042)	(0.027)	(0.038)
Non Patent Literature Cited	1.002	1.001	1.001	1.001
	(0.002)	(0.003)	(0.002)	(0.002)
Mean Age of Backward Cites	1.014	1.018	1.013	1.020
	(0.018)	(0.019)	(0.013)	(0.017)
Application Year Fixed Effects	YES	YES	YES	YES
Class Group Strata	YES	YES	YES	YES
Constant			0.087***	0.054***
			(0.054)	(0.036)
Number of Observations	701	701	701	701

Robust Standard Errors in Parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Cox Proportional Hazards Models

Hazard Ratios Reported.

	(1)	(2)	(3)	(4)	(5)	(6)
Time at risks starts at disclosure to:	USPTO	USPTO	USPTO	USPTO	USPTO	USPTO
Sample Includes	LICENCED ONLY	LICENCED ONLY	LICENSED and UNLICENSE D (excl. censored)	LICENSED and UNLICENSED (excl. censored)	LICENSED and UNLICENSED (incl. censored)	LICENSED and UNLICENSED (incl. censored)
Allowed	1.607* (0.432)	0.668 (0.304)	1.346 (0.381)	0.753 (0.340)	0.974 (0.274)	0.621 (0.272)
Allowance Lag	0.994* (0.004)	1.000 (0.004)	1.004 (0.004)	1.007* (0.004)	1.005 (0.004)	1.007 (0.004)
Issued		5.334*** (2.299)		2.727** (1.178)		2.096* (0.866)
Forward Cites per Year	1.029 (0.026)	1.020 (0.034)	1.069** (0.035)	1.073** (0.036)	1.091** (0.037)	1.092*** (0.037)
Number of Cited Patents	1.000 (0.004)	1.004 (0.004)	1.006 (0.005)	1.007 (0.005)	1.009 (0.006)	1.010* (0.006)
Device	1.217 (0.261)	1.119 (0.283)	0.715 (0.184)	0.683 (0.183)	0.725 (0.181)	0.718 (0.180)
Number of Unique 4-Digit IPCs	1.026 (0.036)	1.006 (0.042)	1.135*** (0.048)	1.136*** (0.050)	1.124*** (0.050)	1.125*** (0.051)
Non Patent Literature Cited	1.002 (0.002)	1.001 (0.003)	1.004 (0.003)	1.004 (0.003)	1.004 (0.003)	1.004 (0.003)
Mean Age of Backward Cites	1.014 (0.018)	1.018 (0.019)	1.011 (0.014)	1.012 (0.015)	1.011 (0.014)	1.011 (0.014)
Application Year Fixed Effects	YES	YES	YES	YES	YES	YES
Class Group Strata	YES	YES	YES	YES	YES	YES
Number of Observations	701	701	1,139	1,139	1,771	1,771

Robust Standard Errors in Parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Cox Proportional Hazards Model

Hazard Ratios Reported

	(1)	(2)	(3)
Time at risks starts at disclosure to:	TLO	TLO	USPTO
	LICENSED and UNLICENSED	LICENSED and UNLICENSED	LICENSED and UNLICENSED
Sample	(excl. censored)	(excl. censored)	(excl. censored)
Filed	2.493** (1.032)		
Allowed	0.658 (0.273)	0.658 (0.275)	0.753 (0.340)
Allowance Lag	1.005 (0.004)	1.005 (0.004)	1.007* (0.004)
Issued	1.760 (0.706)	1.698 (0.680)	2.727** (1.178)
Forward Cites per Year	1.081** (0.036)	1.087** (0.036)	1.073** (0.036)
Number of Cited Patents	1.011** (0.005)	1.010** (0.005)	1.007 (0.005)
Device	0.802 (0.196)	0.801 (0.195)	0.683 (0.183)
Number of Unique 4-Digit IPCs	1.132*** (0.049)	1.130*** (0.049)	1.136*** (0.050)
Non Patent Literature Cited	1.006 (0.003)	1.005 (0.003)	1.004 (0.003)
Mean Age of Backward Cites	1.006 (0.014)	1.005 (0.013)	1.012 (0.015)
Application Year Fixed Effects	YES	YES	YES
Class Group Strata	YES	YES	YES
Number of Observations	1,980	1,980	1,771

Robust Standard Errors in Parentheses

*** p<0.01, ** p<0.05, * p<0.1