Pendency and Thickets

Marek Dietl[*a], Łukasz Skrok[a], Pablo Benalcazar[b], Mateusz Gątkowski[1c,d], Katharine Rockett[e]

[a]*Warsaw School of Economics, Department of Business Economics, Warsaw, Poland*
[b]*Polish Academy of Sciences, Mineral and Energy Economy Research Institute, Cracow, Poland*
[c]*University of Essex, Department of Economics, Wivenhoe Park, Colchester CO4 3SQ, UK*
[d]*University of Essex, Centre for Computational Finance and Economic Agents (CCFEA), Wivenhoe Park, Colchester CO4 3SQ, UK*
[e]*University of Essex, Department of Economics, Wivenhoe Park, Colchester CO4 3SQ, UK*

Abstract
This article empirically investigates the results of an expert-based method to identify 'patent thickets' for a unique USPTO dataset. The research aims to identify the overall effect of patent thickets on patent pendency. We find that patents belonging to a thicket are, on average, granted protection sooner. At the same time, we show that patent groups with higher thicket frequency have higher average pendency time, as do patents within larger thickets. Both suggest spillovers in processing time across patents. We additionally find mild support that the first patent in a thicket has a longer pendency period.

Keywords: Intellectual Property, Patenting, Patent Thickets, Pendency Time
JEL Classification: L13, L20, O34

[1] Part of the research was supported by the National Science Center (NCN), grant No. DEC-2013/11/B/HS4/00682 "A new method for identification of patent thickets"
University of Essex, Department of Economics affiliation is an honorary agreement

1. Introduction – patent thickets, quality of patents and pendency time

A robust literature has developed diagnosing the factors underlying the growth in patent filing over the past thirty years (Kortum and Lerner, 1999, and Hall and Ziedonis, 2001). This has included a spate of papers focussing on strategic effects in the presence of patent thickets, defined as “an overlapping set of patent rights requiring those that seek to commercialize new technology obtain licenses from multiple patentees” (Shapiro, 2001). While many of these have been generally negative on the innovation and diffusion incentives in the presence of thickets (Heller and Eisenberg, 1998, Eisenberg, 2001, and Jaffe and Lerner, 2004), more recent papers (Galasso and Schankerman, 2010, and Lichtman, 2006) have been positive.

Thickets clearly exist (Shapiro, 2001), and both anecdotal evidence and data work suggest that they induce strategic effects. Lemley and Shapiro (2005) note that companies may file numerous patents to increase their chances of covering a technology that would become widely used, hoping to receive royalties from licensing their intellectual property. Hall and Ziedonis (2001) provide support for this approach by studying patenting behaviour in semiconductors, where thickets are present, via both empirical work and interviews. They reveal that larger firms use patents to amass bargaining chips as a strategic response to hold up and as part of a “patent portfolio race”, while smaller design firms use them to secure “bulletproof” rights to niche technologies to acquire venture capital funding. Galasso et al (2013) further bolster this view by observing that trading patents to a large patent holder significantly reduces the risk of litigation, suggesting that “plugging holes” is an important role for individual patents, as is consolidation in the hands of a firm that can use such patents in settlements that avoid the courtroom when disputes arise. Ziedonis (2004) and Noel and Schankerman (2013) find that patenting activity rises in the presence of fragmentation, supporting the view that hold up can potentially raise the incentives to patent. Galasso and Schankerman (2010) extend this to showing that fragmentation tends to decrease delay overall in patent settlements due to the interaction of the value of the underlying patents with fragmentation. They also note that the existence of substitutes can affect litigation delays. Finally, Hall et al (2015) present a nuanced view, separating out the effect of hold up in thickets, with a negative effect on entry, from the effect of complexity, with a positive effect. They associate complexity with the possibility of developing a technology in a way that has few competitors, whereas hold up is associated with entry costs.

The effects of thickets on the delay in obtaining a patent grant (“pendency”) – and conditional upon entry - has not been studied systematically. Matutes et al (1996) suggest that a wide set of applications of an initial “fertile” idea should result in changes in the writing of patents as initial patent holders attempt to capture rights to future spin-offs. While this has implications for delay associated with the first patent in a thicket they do not conduct an empirical exploration to gauge the magnitude of this effect. Popp, Juhl and Johnson (2004) find in interviews of patent examiners that the breadth of claims writing matters to pendency. Their empirical work suggests that crowded technology fields may have a longer or a shorter pendency, depending on how interference among competing claims interacts with a quicker search for prior art. Other papers have looked at patent pendency, but have not addressed thicket issues specifically. Harhoff and Wagner (2009) note that the patent grant carries important strategic, legal and financial implications separate from the patent application.

Hence, applicants should be willing to invest effort in pushing through patent applications where they anticipate more valuable income streams. The patent application process should be affected by many considerations, however. Regibeau and Rockett (2010) reinforce this point, and bolster it by adding examiner process effects such as learning about technologies as patents accumulate in a technology area.

None of these papers investigate the effect of thickets on pendency empirically, a gap that we address. Observing the effect of thickets on pendency is important in its own right: the workings of the patent examination process are important for innovation incentives. Furthermore, behaviour at this stage can serve to confirm or question previous results on strategic incentives to obtain patents where thickets are present. Our results are complementary to the results of Hall et al (2015) in the sense that we study the effect of thickets conditional upon entry into a technological area, whereas they examine the effects on entry itself.

The patent examination process carries its own analytical challenges, of course, which must be incorporated into our empirical work. To illustrate, we should observe greater urgency and shorter pendency times for patents in a thicket if we view them as bargaining chips or the means to create an unassailable collection of rights. On the other hand, in the presence of thickets, the examiner's task of disentangling the rights to a technology via the claims approval process should become more difficult, as suggested by Popp et al (2004). Furthermore, Lemley and Shapiro (2007) suggest that applicants may purposefully delay the issuance of their patents to "take companies by surprise". While more recent patent publication deadlines of 18 months from filing in the US have reduced the possibilities for this type of "submarining", Harhoff and Wagner (2009) suggest that uncertainty in the precise metes and bounds of the patent may have strategic value of its own. This uncertainty would be present during the pendency period regardless of disclosure at 18 months.

Taken together, then, the literature has identified several effects that may affect pendency in the presence of thickets: increased complexity in examination and the desire to increase uncertainty should both have a positive effect, while the desire to build a solid portfolio should have a negative effect. The combined effect of these opposing forces is the empirical question that we study here. We collect a sample of patents that do or do not belong to thickets, as measured by the views of technology experts. This is a novel, but direct, way to measure patent thickets and is set out in detail in another paper (Gatkowski et al, 2017). After presenting our data and methodology, we move to our results.

Our main result is that the effect of thickets on individual patent pendency is – overall - negative, which confirms the view that thickets are associated with an increased urgency to obtain full patent rights (conditional upon entry). In other words, if we control for the technological and structural characteristics of a patent, which should themselves affect delays, we find that being in a thicket tends to decrease delay further. This does not negate the positive effects of thickets on delay, but suggests that empirically the negative effects dominate.

At the same time, we find that the ratio of thickets to the total patents in a technology group increases pendency aside from the fixed effect of the group itself. A possible interpretation is that an externality exists among patents in technology groups associated with thickets, slowing down the process for the group overall even if patents belonging to thickets proceed faster. Bolstering the view of externalities among patents, we find a positive effect of the thicket size (or "count") on pendency times within the thicket. This effect loses significance when controls for examiners and attorneys are added, which may be because of the general decrease in significance due to the large reduction in degrees of freedom or because attorney and examiner effects largely absorb thicket count. This could be the case if, for example, certain attorneys and examiners were associated with the type of thicket that is generated.

We find some evidence of increased delay of the first thicket in a patent, suggesting that firms may anticipate future work and put more care into the writing of "pioneer" applications. We find only mild evidence of shorter delays among filers with larger patent holdings: with all controls added this loses significance and even changes sign.

The paper is organised as follows. Section 2 presents our methodology and data, including our method of measuring thickets using expert opinion. Section 3 presents our results. We have been selective in what we report, so some of our results are summarised in the text only. Section 4 concludes.

2. Methodology and Data

We conducted econometric analysis of a combined USPTO dataset and a unique qualitative assessment of patents. The qualitative assessment was conducted by subject matter experts in fields to which the patents belonged. The complete dataset consists of 12,312 patents from 58 patent groups (listed in Appendix 1) and contains information on the filing company, application and granting dates, and the number of claims. The USPTO dataset was further complemented with publicly available aggregated data.

Eight subject matter experts were selected to review patents in 58 patent groups. Each was asked to identify patents belonging to patent thickets and assess the innovativeness of each patent. From their qualitative assessment, 307 patent thickets containing 2732 patents were identified. To standardise their work a thicket definition coined by Shapiro (2001) was selected: "Patent thickets are dense webs of overlapping intellectual property rights owned by one or more different companies (patent owners), which create a potential high cost in commercializing a new technology, and this cost is difficult to assess upfront." They were asked to identify the overall significance of the patent's contribution to the field as a measure of innovativeness.

Identifying patent thickets this way allows us to capture flexibly any linkages among patents including complementarity, citation and substitutability links. On the other hand, it is subjective so we must use the measure under the implicit assumption that the experts are correct[2].

[1] Here, we do not separate out complementary and substitution links, as in Galasso and Schankerman (2010). We leave a full discussion of our method to other work, see Gatkowski et al (2017).

The complete data used in the econometric model consists of:

a) individual data from the USPTO on patents granted in specific patent USPC groups, which reflect a variety of disciplines such as: chemistry (e.g. crystallization), electricity (e.g. fault detecting), drugs (e.g. antibodies), dentistry, bleaching and dyeing, nanostructure).

   The first patent in the sample was granted on 06.01.1976 and the most recent on 24.03.2015; the data contains information drawn from all patents within the group and including: filing date, grant date, USPC groups, assignee, number of claims, examiner and attorney. Forward citations are the first four years of citations after grant while backwards citations include all references. This measure is, then, standardised for all patents in the dataset even if more data is available, as is standard in the literature, to prevent sample truncation effects. As changes in patent legislation were enacted in the middle of our sample period, we conduct robustness tests that separate out the data into two groups pre and post 2001. Finally, it is important to the results that our technology groups are "narrow" rather than "broad", since the narrow groupings allow us to control specifically for the place of each patent in its technology cycle. This is important to isolating learning effects, as pointed out by Régibeau and Rockett (2010).

b) data on the total number of applications filed and patents granted by the USPTO (2016a) during the period 1976-2014, which were used in our initial experiments.

c) total expenses of USPTO during the period 1992-2014 (based on USPTO, 2016b) were included in initial experiments.

d) expert-identified sets: a) patents belonging to a thicket, b) 'innovativeness' of a patent (measured on five-point scale). The latter is a proxy for both a 'value' and a 'novelty' of a technology – which, in literature, is usually approximated by forward and backward citations. While we benefit from a broad conception of innovativeness (including pure scientific merit) with this methodology, we rely on the subjective evaluations as being a true reflection of how novel the underlying technology is. We also use forward and backward citations to measure value independently in a manner closer to the literature.

To minimize the possibly distorting effect of sample selection and truncation at the margins of the covered period, we have limited the sample to the patents that were filed between 1976 and 2010. The resulting sample consists of 8,644 patents. For specifications that included USPTO expenses, only used post-1992 data was available for all data, so the dataset shrinks to 7,111 observations.

We investigate the connection between thickets and pendency time, where pendency time is the dependent variable, calculated as the difference between the grant date and the filing date, and expressed in number of days. To diagnose effects more finely, we additionally include:

- 'Belonging to a thicket (patent later than the first)' – a binary variable which indicates whether a patent was identified by an examining expert to be a part of a thicket, but without patents for which 'First patent in a thicket' is 1 (see below).

- ‘First patent in a thicket’ – this binary takes the value of 1 when a patent has the earliest filling date within its thicket.
- Thicket count – is the number of patents in a thicket to which a given patent belongs, measured within the universe of patents reviewed by the experts. The variable takes a value of 0 for non-thicket patents.
- Thicket ratio – a group-level variable. This is the number of patents belonging to any thicket divided by the total number of patents in a given group (in accordance with the USPC classification) within the analysed sample.

Control variables include claims per patent and number of USPC patent groups to which a patent was assigned as a reflection of examiner task complexity. Complexity of the patent’s coverage is also controlled for by the number of backward citations within field and the number of technology groups to which the patent was assigned. We also control for innovativeness, which is a grade assigned to a patent by experts based on the overall contribution of the patent to the field with values of: 1 – very low innovativeness; 2 – low innovativeness; 3 – medium innovativeness; 4 – high innovativeness; 5 – very high innovativeness. This can be taken as a reflection of novelty. Value is controlled for more narrowly by forward citations by patents filed for no later than during the next four years[3].

[3] Forward citations are calculated only within our sample – so they are limited to the groups in our sample and patents granted no later than on 24.03.2015.

Table 1. Descriptive statistics for the variables used in regression models.

Variable	Aggregation level	Average/ proportion	Median	Minimum	Maximum	Standard deviation
Pendency time (dependent variable)	Individual patent	952	837	53	5,473	505
Belonging to a thicket (patent later than the first)		17.5%	Binary variable			
First patent in a thicket		2.5%	Binary variable			
Number of claims		17	14	1	303	14
Number of groups		6.76	5	1	99	5.71
# of backward citations		1.81	1	0	75	4.02
# of earlier successful applications		394.8	273	1	1885	351.72
# of forward citations		0.65	0	0	29	1.79
Having > 4 previous patents		35.7%	Binary variable			
Innovativeness: very low		1%	Binary variable			
Innovativeness: low		24%	Binary variable			
Innovativeness: medium		57%	Binary variable			
Innovativeness: high		15%	Binary variable			
Innovativeness: very high		3%	Binary variable			
Thicket count	Thicket	7.44	3	1	89	10.98
Thicket ratio	Group of patents	0.24	0.21	0	0.76	0.19
No of applications to USPTO in a year of applying (in thousands)	Year	243	189	108	520	132
No of patents granted by USPTO in a		123	110	52	244	51

year of applying (in thousands)					
USPTO budget in a year of applying (in Billion USD, 2014 prices)	13.9	13.6	5.9	22	5.1

Source: Own estimates.

The results of five different models are presented, although our commentary reflects many other experiments that we do not report. The general specification is as follows:

$$time_i = \alpha + \beta X_i + \gamma Y_{j(i)} + \delta Z_{k(i)} \theta T_{t(i)} + \varepsilon_i \quad (15)$$

where *i* denotes a patent, $j(i)$ a thicket to which patent *i* belongs (if it does to any), $k(i)$ a patent group to which patent i belongs and $t(i)$ a filling year for patent *i.* X, Y, Z and T stand for matrices of (continuous or dummy) variables describing, respectively, patents, thickets, groups and years.

The estimation method is OLS (ordinary least squares)[4]. Reported p-values for standard errors have been estimated using heteroscedasticity-corrected estimators suggested by MacKinnon and White (1985).[5]

3. Results

Our main results are presented in table 2. Five experiments are presented in the five columns, each with different set of controls, listed at the bottom of the table. The first equation is the baseline, grouping all the data together. It includes workload information from the USPTO but otherwise excludes controls for technology groups, years, attorneys and examiners. The second column adds budgetary information for the USPTO, the third eliminates the workload and budgetary information but includes a control for each year, the fourth adds to this a control for technology group and the final column adds controls for attorneys and examiners. Each column adds to the understanding of the explanatory variables, listed in the left hand column. Pendency is the dependent variable for all experiments. Results for controls are included in Appendix 2, rather than in the main table.

Taken together, these five versions all suggest that patents belonging to a thicket have, on average, shorter pendency times - depending on the type of specification - of 2.5-4 months. Given that the average patent has a pendency of about two to three years, this is a strong reduction. When we divide up our data into pre-2001 and post-2001 periods, we see that the thicket effect becomes generally stronger in the latter period even when controls for thicket size are added. In terms of whether this effect is due to the technical complexity of the group rather than the existence of the thicket in the sense of hold up, as noted by Hall et al (2015), we note several points. First, the effect is present even when we control for narrow technology group, and we see the effect regardless of controlling for backwards citations, number of claims, and the number of groups to which the patent belongs. The underlying

[4] All estimation conducted in R.
[5] In particular, the HC1 estimator has been used.

complexity of the technology itself should be filtered out by these controls, even if the control is not the same as in the Hall et al (2015) paper. The result is very stable across experiments.

This result does not apply, however, to the earliest application in each thicket. This might be expected if the development of the thicket is not well anticipated: the first patent in the thicket is not yet in a thicket, after all. Indeed, the coefficient is not significant and remains small until we reach column five.

With all controls for attorneys, examiners, groups and years the pendency time for the first-in-thicket patent becomes significant and positive. The change when we control for examiners and attorneys is remarkable, and suggests that stripped of the confounding factors, a first-in-a-thicket patent would be granted more than 2 months later than the benchmark (not-in-a-thicket) patents. This is true even when we control for special features that might characterise these patents, such as the number of claims, and the innovativeness of the patent.

This result is consistent with Matutes et al's (1996) contention that, when future innovations are anticipated, filers should delay first patents in a group of related work so as to include as many claims as possible and to write each claim as broadly as possible. We control directly for additional claims. Those have a consistent positive effect, which Regibeau and Rockett (2010) and Harhoff and Wagner (2009) interpret as reflecting the complexity of the review process. Any additional strategic effect via the writing of claims, and which appears during the pendency period rather than before filing, works via secrecy in the Matutes et al (1996) model. In our data, however, secrecy during the entire pendency period is only the case in the earlier portion of our data (pre 2001). After 2001, applications were published after 18 months, which is about half of the average pendency period. When we isolate pre- and post-2001 periods we lose significance for our separate measure of the first patent in the thicket when all controls are added. Focussing on the first four columns, however, the effect is, indeed, positive for the pre-2001 period and significantly negative for the post-2001 period. Hence, there is modest support for a significant effect of "care" in writing the claims for pioneer patents.

Groups that contain a higher ratio of patents identified to be part of a thicket have, on average, a substantially longer pendency time. Indeed, this is one of the strongest effects in the results. Hence, while an individual patent that belongs to a thicket receives less delay the overall effect of thickets is to increase delay for the group. This would be consistent with the view that additional complexity in review spills over to other patents. A clear channel for this is workload constraints[6]. The idea that thickets increase the complexity of review is supported by the positive but small coefficient on the number of patents in a thicket (thicket count). The additional effect of a larger thicket on review times loses significance when we control for examiners and attorneys. This may be due to the large loss of degrees of freedom when we include controls for all these agents or it may be because examiners and attorneys tend to be associated with certain types of patent filings.

After presenting the variables directly related to thickets, we separately report results for additional controls relating to the complexity of review (as well as of technology) and the effects of experience. There are a few interesting findings.

[6] This variable is dropped once we insert group controls, as in columns four and five, since it is redundant.

The number of patent groups to which each patent has been assigned - as a measure of interdisciplinarity – enters positively, although unsurprisingly the effect disappears when we control for group, since interdisciplinarity may be largely related to the technology class.

The number of earlier applications within the technology group enters negatively in the last two columns, which are the appropriate focus since group and attorney/examiner effects will be confounded with the results in the first three columns. We interpret this negative sign as a learning effect by examiners and filers alike, as in Regibeau and Rockett (2010). Indeed, that paper points out that controlling narrowly for technology is important to having a negative effect (of learning), rather than a positive effect. Indeed, the pattern of sign, moving from positive to negative as we add controls, is the one that they underline in their paper so we take our results as consistent with theirs.

We also see a negative effect and significant effect of patent portfolio size in the first three columns. This is consistent with the view that larger holders may have increased incentive to push through their patents regardless of learning effects: a secure patent portfolio may be a powerful tool, as Galasso et al (2013) and others, summarised above, have argued.

In keeping with the literature, the number of forward citations enters negatively: forward citations can measure value of the invention, and a higher value would generate urgency in review so that the larger profit stream could be moved forward.

The number of backward citations to references, as a measure of complexity of review as well as of technology, enters positively as one would expect and consistently with the results of Popp, Juhl and Johnson (2004). Workload measures at the USPTO level enter predictably, with a surge in applications increasing pendency and a surge in grants reducing it (since workload reflects "active" applications). Contemporaneous budget measures are associated with increased pendency, but since the budget grows in response to pendency (among other factors), and grows over time, we take the positive coefficient as a reflection of the underlying process driving both budgets and pendency jointly in the face of rising overall applications.

The differences in pendency time between patent groups are statistically and economically significant, as are the effects of examiners and attorneys, following Cotropia et al (2013) and others. Notably, some areas where there has been controversy about patentability, such as recombinant DNA technology, exhibit significantly longer pendency times. Equally, some areas where there has been some pressure to release commercial results earlier, such as surgery or therapeutic devices, exhibit significantly shorter pendencies. It is also the case that pendency time has decreased significantly over the period we study, although this effect shows up mainly post-2001. Innovativeness enters positively, but not significantly even if we aggregate categories of innovativeness[7]. We interpret this as suggesting that scientific merit does not in itself affect the pendency process either via the evaluation of novelty or by the effect of experience.

Finally, the results in the last column have two features that reflect the inclusion of dummies for attorneys and examiners. First, the constant is larger and reflects the time that the (arbitrary) patent in the "undummied" group took to be reviewed. This constant does not, then, have any particular significance in itself since it reflects the characteristics of an arbitrary actor in the process. Second, the large change in degrees of freedom reflects the fact

[7] These are available from the authors upon request.

that we controlled for individual attorneys and examiners at a detailed level rather than simply controlling for those who handled a larger number of patents.

Table 2. Regression Results (dependent variable – pendency in days)

	I	II	III	IV	V
Belonging to thicket (after the first)	-98.378*** (20.082)	-121.172*** (23.850)	-98.972*** (19.918)	-123.025*** (19.661)	-80.987** (33.025)
First patent in thicket	12.019 (32.404)	-3.435 (38.140)	1.925 (31.919)	-2.321 (28.567)	87.435** (41.608)
Thicket count	1.271** (0.541)	1.386** (0.617)	1.310** (0.535)	1.783** (0.560)	1.009 (0.843)
Thicket ratio for group (%)	297.797*** (38.595)	380.472*** (49.213)	302.657*** (38.345)		
Number of claims	2.737*** (0.418)	2.636*** (0.479)	2.502*** (0.415)	2.574*** (0.408)	2.762*** (0.664)
Number of groups	8.858*** (1.130)	8.380*** (1.132)	8.870*** (1.137)	-0.220 (1.051)	-2.754 (2.066)
Number of backwards citations	6.525*** (1.436)	5.800*** (1.444)	5.058*** (1.451)	7.140*** (1.545)	6.826** (2.986)
Number of earlier successful applications	0.100*** (0.020)	0.089*** (0.020)	0.098*** (0.020)	-0.101*** (0.031)	-0.133** (0.058)
Number of forward citations	-42.570*** (2.442)	-44.246*** (2.793)	-42.275*** (2.461)	-39.870*** (2.290)	-32.268*** (4.074)
Number of previous patents > 4	-28.661*** (11.097)	-29.124*** (12.555)	-32.038*** (11.056)	-15.832 (11.098)	18.730 (21.933)
Applications in year (thousands)	2.016*** (0.118)	3.710*** (0.383)			
Patents granted in year (thousands)	-3.322*** (0.305)	-4.786*** (0.413)			
USPTO budget (billion USD, 2014 prices)		16.110*** (3.152)			
USPTO budget squared		-1.603*** (0.254)			
Controls:					
Innovativeness	Y	Y	Y	Y	Y
Group	N	N	N	Y	Y
Year	N	N	Y	Y	Y
Attorney/examiner	N	N	N	N	Y
Constant	680.545*** (59.952)	489.838*** (86.471)	573.387*** (66.429)	654.892*** (70.670)	2223.291*** (258.000)
Observations	8644	7111	8644	8644	8644
R^2	0.134	0.136	0.154	0.212	0.696
Adjusted R^2	0.133	0.134	0.149	0.203	0.396
Residual Std Error	470.156 (df = 8627)	490.397 (df = 7092)	465.632 (df = 8595)	450.869 (df = 8542)	392.380 (df = 4357)
F Statistic	83.768*** (df = 16; 8627)	62.068*** (df = 18; 7092)	32.644*** (df = 48; 8595)	22.735*** (df = 101; 8542)	2.322*** (df = 4286; 4357)

*Note: *p<.1, **p<.05, ***p<.01. Source: Own Estimates*

4. Conclusions

Our results support recent findings relating fragmentation and the incentive to obtain patents, but extends them to the pendency period when the patent grant is at stake rather than the application or entry into the technological field. We see a negative relationship between pendency time and belonging to a thicket, which we interpret as the effect of stronger incentives to push thicket patents through the examination process. We also observe, what we propose to interpret as spillovers in pendency times where thickets are present, as larger thickets and a larger ratio of thickets in a technology group both carry a positive effect on pendency times. A plausible mechanism exists for spillovers: limits on total workload may mean that lower pendency times for certain types of patents result in larger pendency times for others. We do not measure these spillovers directly, but if we take this mechanism at face value this potential spillover suggests that the overall effect of thickets on pendency may not be to shorten it overall even if individual patents are moved forward in the review process.

Additionally, we observe that the first patent in a thicket may have longer pendency, which may reflect broader claim drafting and modestly supporting the contention of Matutes et al (1996) on strategic effects. We see greater experience playing a role at all levels in our data, and a general move towards shorter pendency times, absent thicket considerations.

We should qualify our results by noting that we used experts to classify patents into thickets, rather than the triples measure proposed by Von Graevenitz et al (2011). While we leave to another paper (Gatkowski et al, 2017) the consideration of the merits of our process versus others, we should note that we used a different expert for each of our technology groupings, following their expertise, so that results that we see persist even when we control for groups. This could be interpreted as robust to errors of individual experts, at the very least. Indeed, when we control for groups rather than aggregating groups together (as we have done in different runs of each of the columns), we see little variance in the thicket coefficients, giving us some confidence in the results. A downside of the method is, of course, that our dataset is smaller since we are limited by the time that the experts could devote to us. This may limit statistical significance in some cases. This is particularly true when we control for attorneys and examiners, at which point we lose many degrees of freedom, and when we add groups since we control for group at the narrow level.

Finally, Popp, Juhl and Johnson (2004) suggest that more complex review processes, as one might expect within a thicket, might result in lower quality review due to constraints on examiner time. If this is the case, the shorter lags we observe for thicket patents might be due to a systematically lower quality of the thicket patent documents. This is an issue that deserves more attention, including investigation of the issue of determining quality of patents. We leave this to future work. Further work could also include adding the complementarity and substitutability measures suggested by Galasso and Schankerman (2010) to diagnose the composition of the expert-identified thickets and an associated analysis of net citations.

References

1) Cotropia C., Lemley, M., and Sampat, B. (2013) “Do Applicant Patent Citations Matter?” *Research Policy* 42, 844–854.
2) Eisenberg, R. (2001) “Bargaining over the Transfer of Proprietary Research Tools”, in R. Dreyfuss, D. Zimmerman, and H. First, Eds. *Expanding the Boundaries of Intellectual Property*. Oxford: Oxford University Press.
3) Galasso, A. and Schankerman, M. (2010) “Patent Thickets, Courts, and the Market for Innovation”, *Rand Journal of Economics* 41(3), 472-503.
4) Galasso, A., Schankerman, M., Serrano, C. (2013) “Trading and Enforcing Patent Rights”, *Rand Journal of Economics* 44(2), 275-312.
5) Gatkowski, M., Whalen, R., Dietl, M., Skrok, L. (2017) “Semantic Distance Within Patent Thickets”, Mimeo.
6) Hall, B., Graham, S., Harhoff, D., and Mowery, D. (2004) "Prospects for Improving U.S. Patent Quality via Postgrant Opposition", *Innovation Policy and the Economy* 4, 115-144.
7) Hall B., Helmers C., Graevenitz von G., Rosazza-Bondibene C. (2015) “Technology Entry in the Presence of Patent Thickets”, *NBER Working Paper 21455*. August.
8) Hall, B., Ziedonis, R. (2001) “The Patent Paradox Revisited: An Empirical Study of Patenting in the US Semiconductor Industry 1979-1985”, *Rand Journal of Economics* 32, 101-128.
9) Harhoff D., Wagner, S. (2009), “The Duration of Patent Examination at the European Patent Office”, *Management Science* 55(12), 1969–1984.
10) Heller M. & Eisenberg, R. S. (1998) “Can Patents Deter Innovation? The Anticommons in Biomedical Research”, *Science* 280(5364), 698–701.
11) Kortum, S. and Lerner, J. (1999) “What is Behind the Recent Surge in Patenting?”, *Research Policy* 28(1), 1-22.
12) Lemley M. (2001) “Rational Ignorance and the Patent Office”, *Northwestern University Law Review* 95(4), 1497–1532.
13) Lemley M. and Sampat, B. (2012) "Examiner Characteristics and Patent Office Outcomes," *The Review of Economics and Statistics* 94(3), 817-827.
14) Lemley M. and Shapiro, C. (2005) "Probabilistic Patents," *Journal of Economic Perspectives* 19(2) 75-98.
15) Lemley M. and Shapiro, C. (2007), "Patent Hold-Up and Royalty Stacking," Competition Policy Center, Working Paper Series qt8638s257, Competition Policy Center, Institute for Business and Economic Research, UC Berkeley.
16) Lichtman, D. (2006) “Patent Holdouts in the Standard-Setting Process”, Chicago Unbound Working Paper 292. May.
17) MacKinnon J. G., and H. White (1985), ‘Some heteroscedasticity consistent covariance matrix estimators with improved finite sample properties’, *Journal of Econometrics*, 29, pp. 305–325
18) Matutes, C., Régibeau, P., and Rockett, K. (1996) “Optimal Patent Design and the Diffusion of Innovations”, *Rand Journal of Economics* 27(1), 60-83.
19) Noel, M. and Schankerman, M. (2013) “Strategic Patenting and Software Innovation”, *Journal of Industrial Economics* 61(3) 481-520.
20) Popp D., Juhl, T., and Johnson, D. (2004), ‘Time in Purgatory: Examining the Grant Lag for U.S. Patent Applications,’ *Topics in Economic Analysis and Policy* 4(1) article 29.

21) Régibeau P, and Rockett, K. (2010) "Innovation Cycles and Learning at the Patent Office: Does the Early Patent Get the Delay?", *Journal of Industrial Economics* 58(2), 222-246.
22) Shapiro C. (2001), 'Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting', 2001, *Innovation Policy and the Economy* (I), 119–150.
23) USPTO (2016a), U.S. Patent Statistics Chart Calendar Years 1963 – 2015, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm.
24) USPTO (2016b), USPTO Annual Reports, https://www.uspto.gov/about-us/performance-and-planning/uspto-annual-reports
25) Von Graevenitz, G., Wagner, S., and Harhoff, D. (2011) "How to Measure Patent Thickets – A Novel Approach", *Economics Letters* 111(1), 6-9.
26) Ziedonis, R. (2004) "Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms", *Management Science* 50, 804-820.

Appendix 1

Table 3. Names of USPC groups used in the analysis.

Class and group	Name
205/251	Electrolytic coating (process, composition and method of preparing composition). Depositing predominantly alloy coating. Gold is predominant constituent. Including arsenic, indium or thallium.
205/564	Electrolytic coating (process, composition and method of preparing composition). Preparing single metal. Gallium, germanium, indium, vanadium or molybdenum produced.
23/295R	Chemistry: physical processes. Crystallization
23/302A	Chemistry: physical processes. Crystallization. Alkali method and ammonium compounds. Ammonium compounds
23/303	Chemistry: physical processes. Crystallization. Alkali method and ammonium compounds. Common salt
23/305A	Chemistry: physical processes. Crystallization. Heavy metal or aluminum compounds. Aluminum compounds
23/305R	Chemistry: physical processes. Crystallization. Heavy metal or aluminum compounds
23/306	Chemistry: physical processes. Concentration of liquids in liquids
23/307	Chemistry: physical processes. Concentration of liquids in liquids. With direct heating
23/313R	Chemistry: physical processes. Agglomerating
324/509	Electricity: measuring and testing. Fault detecting in electric circuits and of electric components of ground fault indication
324/512	Electricity: measuring and testing. Fault detecting in electric circuits and of electric components for fault location
324/525	Electricity: measuring and testing. Fault detecting in electric circuits and of electric components for fault location by resistance or impedance measuring
345/427	Selective visual display systems. Computer graphics processing. Three dimension. Space transformation
345/9	Selective visual display systems. Image superposition by optical means. Plural image superposition
348/67	Television. Improving the 3D impression of a displayed stereoscopic image
382/107	Image analysis. Applications. Motion or velocity measuring
382/209	Image analysis. Pattern recognition. Template matching
424/114	Drug, bio-affecting and body treating compositions. Plural fermentates of different origin
424/195.16	Drug, bio-affecting and body treating compositions. Extract or material containing or obtained from a unicellular fungus as active ingredient
424/78.01	Drug, bio-affecting and body treating compositions. Digestive system regulator containing solid synthetic organic polymer
424/78.02	Drug, bio-affecting and body treating compositions. Topical body preparation containing solid synthetic organic polymer
424/78.08	Drug, bio-affecting and body treating compositions. Solid synthetic organic polymer
424/780	Drug, bio-affecting and body treating compositions. Extract or material containing or obtained from a micro-organism as active ingredient
424/800	Drug, bio-affecting and body treating compositions. Antibody or fragment thereof whose

	amino acid sequence is disclosed in whole or in part
424/801	Drug, bio-affecting and body treating compositions. Involving antibody or fragment thereof produced by recombinant dna technology
424/802	Drug, bio-affecting and body treating compositions. Antibody or antigen-binding fragment thereof that binds gram-positive bacteria
424/803	Drug, bio-affecting and body treating compositions. Antibody or antigen-binding fragment thereof that binds gram-negative bacteria
424/804	Drug, bio-affecting and body treating compositions. Involving IGG3, IGG4, IGA, or IGY
424/805	Drug, bio-affecting and body treating compositions. Involving IGE or IGD
424/806	Drug, bio-affecting and body treating compositions. Involving IGM
424/807	Drug, bio-affecting and body treating compositions. Involving IGM. Monoclonal
424/808	Drug, bio-affecting and body treating compositions. Involving IGM. Human
424/94.1	Drug, bio-affecting and body treating compositions. Enzyme or coenzyme containing
433/215	Dentistry. Method or material for testing, treating, restoring, or removing natural teeth
435/6.19	Chemistry: molecular biology and microbiology. Involving nucleid acid. Detectic nucleic acid by specific antibody, protein or ligand-receptor biding assay
435/7.7	Chemistry: molecular biology and microbiology. Involving antigen-antibody binding, specific binding protein assay or specific ligand-receptor binding assay. Assay in which a label present is an apoenzyme, prosthetic group, or enzyme cofactor
435/7.71	Chemistry: molecular biology and microbiology. Involving antigen-antibody binding, specific binding protein assay or specific ligand-receptor binding assay. Assay in which a label present is an enzyme inhibitor or functions to alter enzyme activity
435/7.72	Chemistry: molecular biology and microbiology. Involving antigen-antibody binding, specific binding protein assay or specific ligand-receptor binding assay. Assay in which a label present is an enzyme substrate or substrate analogue
435/7.93	Chemistry: molecular biology and microbiology. Involving antigen-antibody binding, specific binding protein assay or specific ligand-receptor binding assay. Assay in which an enzyme present is a label. Competitive assay
435/7.94	Chemistry: molecular biology and microbiology. Involving antigen-antibody binding, specific binding protein assay or specific ligand-receptor binding assay. Assay in which an enzyme present is a label. Sandwich assay
435/7.95	Chemistry: molecular biology and microbiology. Involving antigen-antibody binding, specific binding protein assay or specific ligand-receptor binding assay. Assay in which an enzyme present is a label. Indirect assay
604/890.1	Surgery. Controlled release therapeutic device or system
8/115.51	Bleaching and dyeing. Chemical modification of textiles or fibers or products thereof
8/400	Bleaching and dyeing. Measuring, testing or inspecting dye process
8/401	Bleaching and dyeing. Using enzymes, dye process, composition, or product of dyeing
8/438	Bleaching and dyeing. Process of extracting or purifying of natural dye
8/443	Bleaching and dyeing. Weighting process
8/493	Bleaching and dyeing. Overall dimensional modification or stabilization. Modification of molecular structure of substrate by chemical means
977/762	Nanostructure. Nanowire or quantum wire (axially elongated structure having two dimensions of 100 nm or less)

977/773	Nanostructure. Nanoparticle (structure having three dimensions of 100 nm or less)
977/778	Nanostructure. Within specified host or matrix material (e.g., nanocomposite films, etc.)
977/810	Nanostructure. Of specified metal or metal alloy composition
977/881	Manufacture, treatment or detection of nanostructure. With arrangement, process, or apparatus for testing. With arrangement, process, or apparatus for testing
977/903	Specified use of nanostructure. For conversion, containment, or destruction of hazardous material
977/904	Specified use of nanostructure. For medical, immunological, body treatment, or diagnosis

Appendix 2

Table 4. Controls used in regression models (dependent variable – pendency in days)

	I	II	III	IV	V
Innovativeness = 1 (very low)				*benchmark*	
Innovativeness = 2 (low)	*12.455*	*7.915*	*9.643*	*23.028*	*-25.306*
	(58.581)	*(68.757)*	*(58.175)*	*(57.845)*	*(84.459)*
Innovativeness = 3 (medium)	*7.567*	*-3.673*	*5.662*	*19.457*	*-33.817*
	(58.032)	*(68.175)*	*(57.683)*	*(57.390)*	*(84.458)*
Innovativeness = 4 (high)	*6.058*	*-3.624*	*3.529*	*42.767*	*-15.428*
	(59.114)	*(69.340)*	*(58.761)*	*(58.681)*	*(86.392)*
Innovativeness = 5 (very high)	*104.018*	*114.806*	*100.783*	*48.094*	*-28.934*
	(68.551)	*(80.960)*	*(68.277)*	*(64.873)*	*(94.345)*
1976				*benchmark*	
1977			*42.775*	*38.652*	*-22.997*
			(48.457)	*(49.368)*	*(159.637)*
1978			*137.873******	*147.414******	*61.111*
			(46.366)	*(47.845)*	*(170.186)*
1979			*52.091*	*47.480*	*-106.413*
			(40.582)	*(42.730)*	*(143.710)*
1980			139.139***	133.360**	1.449
			(50.973)	(53.205)	(142.966)
1981			119.300***	107.786**	20.058
			(42.872)	(43.698)	(142.306)
1982			210.921***	158.724***	-27.653
			(45.481)	(47.330)	(144.052)
1983			121.464***	83.411*	-24.302

	(47.092)	(45.975)	(150.253)
1984	179.142***	113.672**	25.531
	(48.899)	(48.275)	(151.951)
1985	159.993***	99.791*	-65.601
	(51.695)	(50.909)	(146.619)
1986	112.624***	90.233**	-76.343
	(42.660)	(43.277)	(145.759)
1987	133.938***	101.019**	-160.568
	(42.275)	(42.261)	(149.306)
1988	65.529	31.682	-188.485
	(44.358)	(44.649)	(154.766)
1989	168.063***	130.029***	-140.395
	(43.626)	(43.967)	(153.133)
1990	52.895	23.948	-288.827*
	(44.064)	(44.709)	(148.991)
1991	66.919	34.783	-319.030**
	(41.962)	(43.375)	(147.649)
1992	80.855*	53.513	-280.411*
	(46.357)	(47.290)	(155.428)
1993	87.852*	48.048	-326.597**
	(44.904)	(45.878)	(152.569)
1994	185.901***	157.129***	-296.144*
	(44.780)	(45.879)	(153.817)
1995	205.361***	181.202***	-310.792**
	(41.853)	(42.912)	(152.322)
1996	138.063***	138.374***	-389.600**
	(39.525)	(41.078)	(151.299)

1997	164.452***	160.968***	-363.730**
	(40.540)	(42.439)	(157.861)
1998	142.745***	165.654***	-418.983***
	(39.378)	(41.022)	(151.690)
1999	134.655***	151.768***	-440.979***
	(41.058)	(42.978)	(152.649)
2000	181.451***	195.048***	-476.516***
	(41.806)	(42.784)	(152.422)
2001	93.470**	121.291***	-527.173***
	(39.840)	(42.556)	(154.171)
2002	246.834***	297.830***	-350.006**
	(44.771)	(47.278)	(157.109)
2003	380.206***	428.364***	-314.214*
	(49.582)	(50.636)	(160.717)
2004	419.586***	475.428***	-272.108*
	(48.363)	(49.634)	(158.638)
2005	533.147***	588.858***	-265.725
	(52.580)	(54.524)	(163.896)
2006	484.120***	550.653***	-272.711*
	(46.725)	(49.344)	(164.053)
2007	502.775***	569.965***	-418.945**
	(44.215)	(47.247)	(164.163)
2008	438.480***	522.953***	-561.224***
	(44.258)	(47.775)	(167.828)
2009	349.198***	423.185***	-653.861***
	(41.300)	(45.130)	(166.075)
2010	188.524***	269.665***	-788.108***
	(40.742)	(45.468)	(167.432)

Group 23/302A	-216.958***	-306.405*
	(52.433)	(160.171)
Group 23/303	81.757	-5.391
	(78.384)	(101.808)
Group 23/305A	-110.523**	-107.775
	(54.440)	(91.965)
Group 23/305R	-17.576	102.605
	(61.618)	(113.821)
Group 23/306	-37.927	60.621
	(82.929)	(136.773)
Group 23/307	38.725	74.765
	(101.580)	(208.829)
Group 23/313R	-41.804	-34.245
	(34.383)	(87.350)
Group 324/509	-92.897***	-36.889
	(31.095)	(141.370)
Group 324/512	-75.422**	47.922
	(33.695)	(141.859)
Group 324/525	-108.152***	-102.505
	(30.337)	(139.964)
Group 327/129	-95.400***	-42.906
	(36.790)	(149.638)
Group 327/142	-88.848***	10.382
	(33.739)	(139.721)
Group 327/143	-75.017**	97.082
	(30.406)	(138.340)
Group 348/67	232.757**	-617.366**

	(93.506)	(294.826)
Group 424/114	100.607**	228.803
	(42.710)	(142.611)
Group 424/195.16	22.114	65.852
	(56.549)	(126.548)
Group 424/78.01	159.769**	122.230
	(62.214)	(122.472)
Group 424/78.02	126.602***	202.835**
	(33.687)	(97.110)
Group 424/78.08	207.205***	217.239**
	(35.503)	(103.428)
Group 424/780	160.089***	0.891
	(57.054)	(116.987)
Group 424/800	87.494	-223.018
	(103.257)	(566.265)
Group 424/801	1,115.605***	737.136**
	(179.074)	(307.041)
Group 424/802	64.890	-405.220**
	(274.032)	(187.271)
Group 424/803	185.297	585.697
	(305.657)	(556.838)
Group 424/804	291.660**	266.049
	(113.387)	(249.319)
Group 424/805	203.487**	39.601
	(88.504)	(182.621)
Group 424/806	305.267	228.155
	(202.630)	(199.881)

Group 424/807	307.302***	79.061
	(92.975)	(201.208)
Group 424/808	292.760	269.807
	(189.202)	(321.965)
Group 424/94.1	167.220***	151.444
	(34.062)	(103.933)
Group 433/1	-113.331	-60.380
	(87.748)	(134.493)
Group 433/133	20.919	32.268
	(42.119)	(127.845)
Group 433/167	2.184	134.055
	(53.256)	(139.550)
Group 433/196	209.133*	265.500
	(118.397)	(215.181)
Group 433/2	-70.827	17.655
	(49.198)	(133.281)
Group 433/215	66.701**	188.854*
	(32.493)	(105.639)
Group 433/229	-46.743	69.268
	(33.456)	(108.578)
Group 433/81	54.384	144.999
	(51.941)	(123.072)
Group 433/86	-7.382	110.639
	(54.089)	(166.235)
Group 436/510	2.991	253.185
	(94.334)	(183.123)
Group 436/512	199.922***	244.686*
	(59.018)	(146.892)

Group 436/536	361.958***	275.828***
	(35.424)	(105.282)
Group 604/890.1	-147.062***	-284.190
	(48.980)	(236.164)
Group 8/115.51	74.482*	135.089
	(40.493)	(106.775)
Group 8/400	-53.809	-30.962
	(40.841)	(150.947)
Group 8/401	-39.937	-99.836
	(43.520)	(116.020)
Group 8/438	-109.480**	-175.387
	(50.607)	(154.841)
Group 8/493	-184.155***	-201.479
	(43.241)	(139.787)
Group 977/778	70.606	241.880**
	(46.461)	(107.599)
Group 977/810	152.553***	468.933***
	(53.478)	(143.631)
Group 977/881	-29.774	38.269
	(40.993)	(127.939)
Group 977/903	-84.700	51.556
	(95.349)	(431.493)
Group 977/904	192.646***	235.327**
	(50.846)	(115.530)
Group 977/963	-31.426	269.361
	(81.252)	(217.655)

*Note: *p<.1, **p<.05, ***p<.01. Source: Own Estimates*