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The coincidence of patent thickets—A comparative analysis

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ABSTRACT

The growth of patent thickets—technology fields that are characterized by a large overlap of rights between different right holders—poses a challenge for innovators. Patent thickets are argued to create strong friction in innovation due to a pronounced potential for holdup. So far, we do not know whether patent thickets coincide in all patent systems or if differences exist that policy makers and managers must take into account when aiming to disentangle and to navigate patent thickets, respectively. To address this gap, we measure patent density of technology fields in the patent systems of the United States, the German patent system governed by the German Patent and Trademark Office (DPMA), and the European patent system governed by the European Patent Office (EPO). Our comparisons reveal both interesting differences and similarities between the analyzed patent systems. Although the United States and the EPO patent system show similar relative patent density patterns across technology fields, the German patent system strongly differs from the previous two. This implies that such deviations need to be taken into account by policy makers when considering regulatory measures as well as by companies in their intellectual property strategy.

1. Introduction

Patent thickets exist in technology fields that are characterized by a large overlap of exclusion rights of different patent holders (Shapiro, 2001). Such thickets should, in theory, not arise because an efficient patent system prohibits overlap. In practice, they do exist and are argued to create large frictions in innovation. When multiple exclusion rights held by different parties overlap, multiple parties can block each other. The resolution of such multilateral blocking relationships involves substantial bargaining costs (Heller and Eisenberg, 1998; von Graevenitz et al., 2011). Furthermore, overlapping patents increase the complexity of patent clearing processes due to the blurring boundaries of single patents, thus increasing the probability of patent infringement (Bessen and Meurer, 2008; Thumm, 2005) and the danger of holdup. Furthermore, there is strong empirical evidence that firms engage in increased patenting when faced with patent thickets, again nourishing their growth (Hall and Ziedonis, 2001; von Graevenitz et al. 2013; Ziedonis, 2004). Scholars and policy makers increasingly debate patent thickets and attempt to adapt patent law or change patent application fee structures to discourage excessive patent filings (for an overview see Jaffe and Lerner, 2004; Graham and Harhoff, 2014).

Recently, von Graevenitz et al. (2011) proposed a novel approach to measure patent thickets relying on European Patent Office (EPO) patent citation data. In their analysis of the patent density of the patent system governed by the EPO, they identified patent thickets in the same technology fields addressed by qualitative studies that mostly discussed the U.S. patent system (e.g. Hall, 2005). Although it is well known that major differences exist in patent application behavior and actual patent usage between different patent systems (e.g. Cohen et al., 2002; for a comprehensive literature overview see Hanel, 2006; Candelin-Palmqvist et al., 2012), it is still an open question whether patent thickets coincide in all patent systems. We address this gap in our understanding of patent systems by applying the patent thicket identification procedure to study differences in patent thickets in the U.S., German, and European patent system governed by the EPO. To do so, we propose modifications to the original algorithm introduced by von Graevenitz et al. (2011). Most notably, we do not make use of citation classifications that only EPO patent citation data provides, but rather rely solely on citation data available in all patent systems.

Our comparison of patent thickets in different patent systems shows interesting differences and similarities between the analyzed patent systems. Although in the United States and the EPO patent system, semiconductors, telecommunications, information technology, audiovisual technology, and optics are the most dense technology fields (however, in different rank orders), in the German patent system, transportation, engines, pumps and turbines, control technology, and

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mechanical elements dominate with respect to patent rights overlap. Our finding that patent thickets coincide between some but not all patent systems provides a particularly important contribution to the current policy debate that so far has neglected differences between patent systems.

2. Literature review

Since innovation is often sequential, patents not only provide incentives to innovations but also can create frictions in it (e.g. Heller and Eisenberg, 1998). Recently, a growing debate has focused on the question of how much the growth of patent thickets, “a dense web of overlapping intellectual property rights” (Shapiro, 2001, *p*. 120), may stifle innovation. First, empirical research on patent thickets provide us with insights about their economic impact. These studies use two different ways to identify the presence of patent thickets.

The first strand of literature relies on a measure for the fragmentation of rights between firms operating in an industry, first introduced by Ziedonis (2004) to study the influence of fragmentation of rights on firm behavior. This indicator, a Herfindahl concentration index, measures the fragmentation of rights on a firm level based on patent citation data. Fragmentation of rights between different right holders in a technology field is a phenomenon that should strongly relate to the existence of a dense web of overlapping rights. Ziedonis (2004) makes use of a fragmentation index to show that firms patent more when faced with patent thickets, thus further nourishing their growth. Noel and Schankerman (2006) show that greater fragmentation is associated with lower market value but higher research and development and, again, higher patenting activity. Cockburn and MacGarvie (2009) show that software start-ups experience more difficulties in obtaining venture capital financing when operating in fragmented technology fields. Cockburn et al. (2010) provide empirical evidence that a negative relationship between fragmentation of rights and innovative performance exists. This effect is particularly strong for firms that do not hold many patents, emphasizing the role of patenting to mitigate the negative effects of patent thickets. Galasso and Schankerman (2009) test the hypothesis that a high fragmentation of overlapping rights can have a positive effect on technology transfer among patent holders by speeding up agreements of settlement. They find some empirical support for this hypothesis, but cannot provide clear results for total dispute settlement time. Such assessment is critical since the presence of patent thickets may speed up settlement duration but increase the number of settlements. Grimpe and Hussinger (2014) on the contrary find no positive effect of fragmentation on engagement in cross-licensing agreements.

The second strand of literature does not target the fragmentation of rights but the overlap of rights to identify patent thickets using the recently proposed triples indicator (von Graevenitz et al., 2011). The triples indicator measures the degree of overlap between patent portfolios of firms on a technology level based on patent citation data. Using the triples indicator and the fragmentation index, von Graevenitz et al. (2013) show that firms patent more when faced with a high degree of overlap between rights and a high degree of fragmentation of rights. Fischer and Henkel (2012) make use of the triples indicator to show that patent trolls, firms that capture value only by enforcing patents, focus on patents in technology fields with a high density of overlapping rights.

While the fragmentation index is useful to study the effects on more or less fragmentation of patent rights on a firm level, the triples indicator offers the opportunity to study the overlap of patents on a technology field level. This allows us to assess for the first time which technology fields hold denser patent thickets and thus suffer from a higher degree of friction created by the patent system. The introduction of the triples indicator allows us, also for the first time, to study differences in patent thicket density between different patent systems, a research gap we aim to close in this article. To do so we chose to compare three important patent systems, the patent systems governed by the U.S. Patent and Trademark Office (USPTO), the EPO, and the German Patent and Trademark Office (DPMA), respectively. One could wonder whether the German patent system governed by the DPMA is not just a subset of the European patent system governed by the EPO. However, DPMA and EPO govern distinct patent systems that use different examination processes, citation rules, and different post-grant quality control measures. As the growth of patent thickets may be due to such differences in legal schemes of the patent systems and particular innovations patented in it, we study patent thickets on a patent system level.

3. Method

3.1. Identifying patent overlap based on patent citations

To obtain a patent, an innovator has to file an application at a patent office. The patent office, in turn, examines the patent with respect to novelty and inventive step. In this examination process, all relevant prior art is referenced using different types of citations. However, the way patent references and, hence, patent citations are awarded differs between patent systems. At the USPTO, applicants have to list prior art themselves while at the EPO or the DPMA it is only examiners who add references to a patent. Also, the amount of information a reference holds differs between patent offices. While USPTO and DPMA do not differentiate the restricting effects of references, the EPO does. In the examination process, an EPO patent examiner rates prior art documents as critical (Type X and Y) when they limit the patentability of the corresponding invention applied for. The EPO examiner places an X reference if the cited document is particularly relevant when taken alone. A Y reference is placed when the cited document is particularly relevant if combined with another document of the same category. There are also other citation types that are not critical for the patent's novelty and inventive step but do lay general grounds of state of the art.

The original patent thicket identification algorithm proposed by von Graevenitz et al. (2011) builds on patent citation data generated in the EPO patent examination process and relies only on critical references. Von Graevenitz et al. (2013) interpret such a critical reference as a blocking relation, where the blocked firm holding the patent that receives the critical reference has to obtain a license from the blocking firm. If two firms have mutual X and Y references, they block each other. Eventually, constellations where three firms are mutually blocking each other (von Graevenitz et al., 2011) form a so-called blocking triple. The more triples that exist in a technology field (classified by the OST-INPI/FhG-ISI technology nomenclature, see OECD, 1994), the denser the patent thicket. The procedure is illustrated in Fig. 1. The algorithm first identifies all patent portfolios of firms holding patents in a technology field. In a next step, it identifies the number of mutual blocking X and Y references between patent portfolios. Finally, it counts how many such mutual blocking dependencies exist between patent portfolios of three firms in the respective technology field.

3.2. Modifications to the original algorithm

To be able to compare patent thickets between different patent systems, we modify the original algorithm. We include all citations of the patents in the patent portfolios, since the differentiation between critical (Type X and Y) references, used by von Graevenitz et al. (2011), and other references is only available for the EPO patent examination process. Furthermore, our Structured Query Language

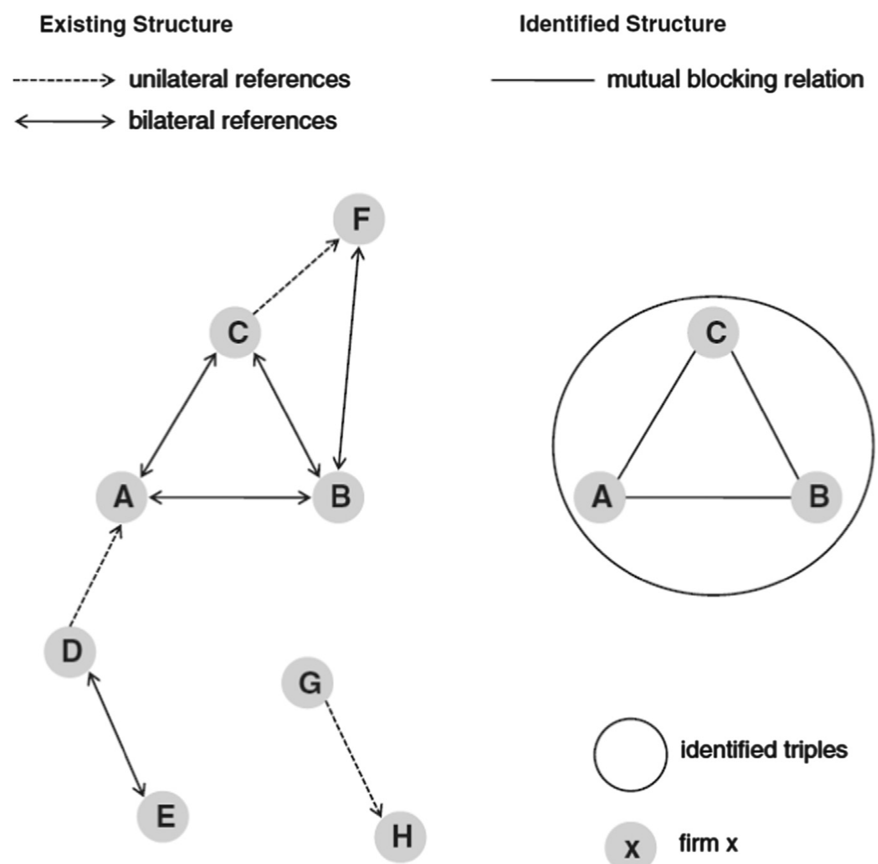

Fig. 1. Illustration of the structure of unilateral, bilateral and multilateral blocking relationships between patent holders (von Graevenitz et al., 2011).

(SQL) implementation of the triples algorithm allows us to relax any restrictions on the number of patentees included that had been used in the original procedure to reduce computational effort. Of course, we expect our modification to impact the number of triples identified but not the distribution over time and across technology fields. In order to estimate the resulting differences in measured patent density, we compare the results of von Graevenitz et al. (2011) with our analysis of patents issued by the EPO. Our calculations are based on 1.7 million patent applications that were applied for at the EPO between 1980 and 2003. Applying the modified procedure to the dataset identifies a total of 8,884 triples, whereupon complex technologies account for 7,667, and discrete technologies for 1,217. Von Graevenitz et al. (2011) find 10,720 triples with 9,247 and 1,472 triples in the respective groups. Furthermore, the authors report three major descriptive results. First, they show the development of thickets in discrete and complex industries over time. Second, they show the difference between complex and discrete industries by the number of patent applications. Third, they compare their findings to extant qualitative findings and find them in line with existing research. A comparison of our descriptive results to the three descriptive results that von Graevenitz et al. (2011) use to validate their triples measure, shows qualitatively the same findings. Fig. 2 shows a comparison of the findings reported in von Graevenitz et al. (2011) and our findings regarding the development of patent density in complex and discrete industries over time for the EPO patent system. The pattern over time is comparable as well as are the differences between complex and discrete industries and the comparison to qualitative findings.

The absolute numbers of identified triples differs between the modified and the original procedure, however. Testing for differences in the distribution of triples between both procedures shows statistically significant differences as expected ($\chi^2 = 49.72$, df$=29$, $p < 0.01$). Fig. 3 and Table 1 illustrate the difference in the share of total triples in the respective technology field identified for EPO patents between 1980 and 2003 between the original and the modified procedure. Although the overall pattern looks similar, differences in some technology fields are not surprising. The original measure should be more accurate because it relies on superior citation data using only critical references obtained from the EPO patent examination process. Our modified approach, on the contrary, uses more noisy citation data without any information on critical and non-critical citations to facilitate cross-system comparisons. We see the most striking differences in absolute terms between the shares of total triples that the respective technology field holds in the field's audiovisual technology, telecommunications, semiconductors, and information technology. The modified algorithm shows that triples in the fields of audiovisual technology, telecommunications, and information technology share more than five percentage points higher and triples in the field of semiconductors more than five percentage points fewer compared with the original algorithm. To shed light on the origins of these differences, we studied selected patent value indicators in the respective technology fields. To do so, we calculate forward citations (as a proxy for quality) and the number of four-digit-level International Patent Classification (IPC) classes the patent is assigned to (as a proxy for scope) for all EPO patents for all technology fields comparing them with the average patent quality and scope. We found no evidence that patent quality or patent scope distort the results of our modified algorithm in a particular direction. In relative terms, looking only at technology fields that have more than one percent triples share to have enough data, the modified algorithm understates by far the number of triples in the field of engines, pumps, and turbines. In this case, we found that this technology field is characterized by particularly low quality patents compared to the average.

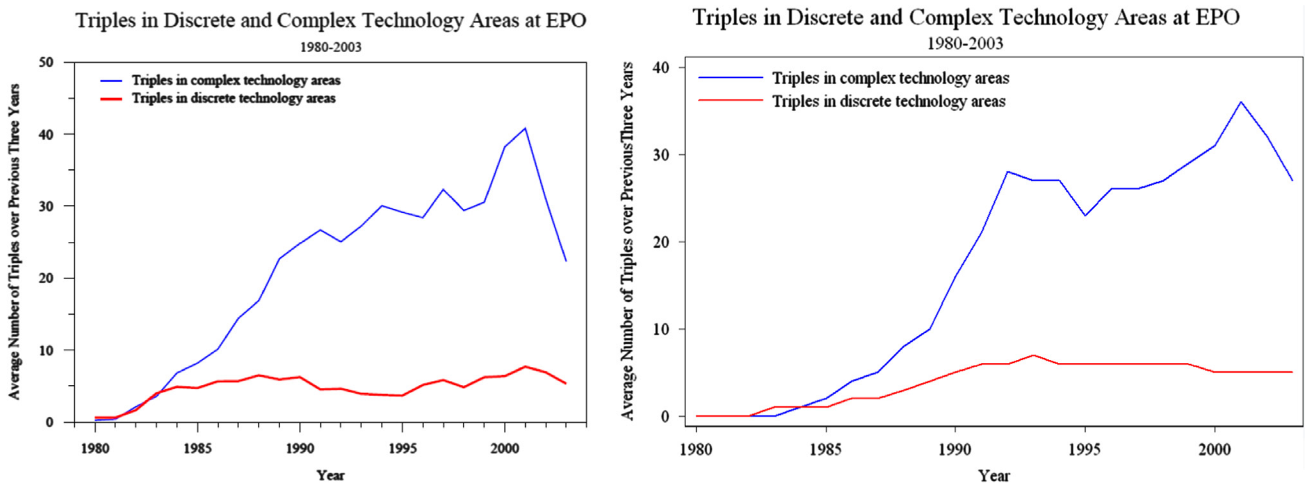

Fig. 2. Triples in discrete and complex technology fields between 1980 and 2003 (3-year mean) (left figure: original algorithm (von Graevenitz et al., 2011); right figure: modified algorithm).

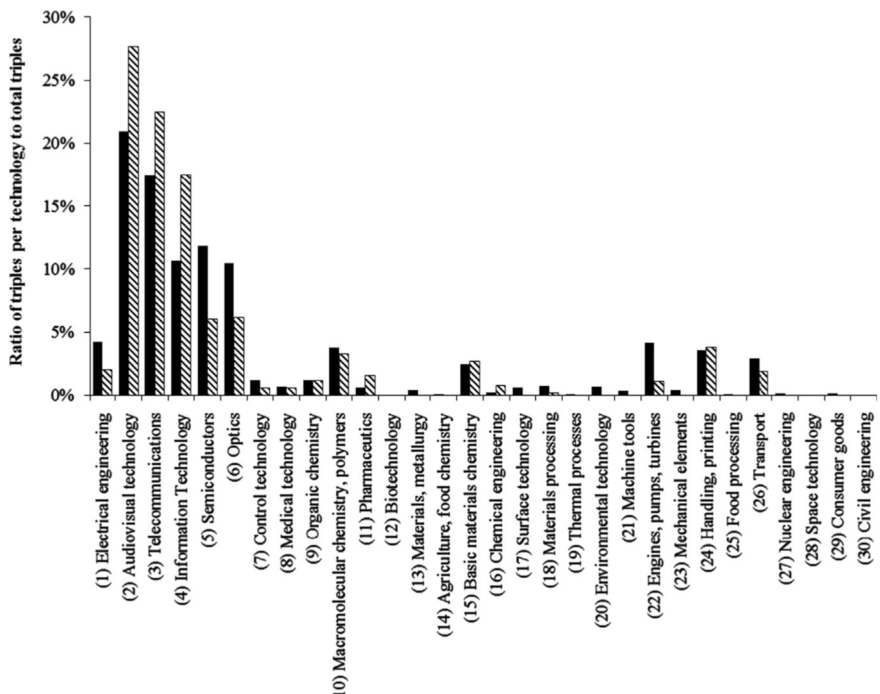

Fig. 3. Identified triples based on EPO patents (1980–2003) across technology fields using the original (dark) and modified (dashed) algorithms (see also Table 1).

We believe that three more explanations exist as to why results of modified and original algorithms diverge. First, we would attribute cases where the modified algorithm identifies more triples than the original to noise in the citation data that the modified algorithm exploits. Furthermore, as the modified algorithm does not use any restrictions on the amount of citations and firms analyzed, it is, in principle, able to detect more triples than the original. On the other hand, we would attribute cases where the modified algorithm finds less triples to worse quality of EPO name standardization in contrast to the manually cleaned dataset that was used in the original algorithm. More patents that accumulate on each firm could lead to fewer mutually blocking relationships between three firms.

To put the patent density we find into perspective, we normalize the number of triples identified by the modified algorithm and compare it to indicators of patent concentration for the respective technology field. Table 2 shows the number of triples normalized by the number of patent applications as well as normalized by the number of different applicants in each technology field for the 10 technology fields with the highest overlap measured by the triples indicator. The different normalizations show comparable patterns with respect to the ranking of the technology fields. Furthermore, in order to put the triples indicator in relation, we compare patent density measured by the modified triples algorithm to two indicators of patent concentration, namely, a Herfindahl index and the share of the top four patenting firms in the respective technology field (Table 2). The Herfindahl index of a technology field is calculated by the sum of the squares of the number of patents applied by each patentee relative to all patents applied in the technology field. Consequently, the higher the value of the Herfindahl index, the more concentrated in terms of patent applicants the technology field can be considered. A similar interpretation applies to the index of the top four patenting firms, although restricted to the top patent applicants. Comparing the indicators across all technology fields reveals, in general, a positive correlation between triples and the concentration of patent applications. This relationship is less pronounced in the

Table 1
Identified triples based on EPO patents (1980-2003) across technology fields using the original and modified algorithms (see also Fig. 3).

Technology field	*Triples mean (yearly, 1980–2003)*		*Share of total triples*	
	Original algorithm	Modified algorithm	Original algorithm	Modified algorithm
Electrical engineering	18.79	7.46	4.21%	2.01%
Audiovisual technology	93.68	102.38	20.97%	27.66%
Telecommunications	78.01	83.38	17.47%	22.52%
Information Technology	47.53	64.71	10.64%	17.48%
Semiconductors	52.72	22.29	11.80%	6.02%
Optics	46.57	22.88	10.43%	6.18%
Control technology	5.45	2.25	1.22%	0.61%
Medical technology	3.15	2.25	0.71%	0.61%
Organic chemistry	5.51	4.38	1.23%	1.18%
Macromolecular chemistry, polymers	16.92	12.08	3.79%	3.26%
Pharmaceutics	2.78	5.71	0.62%	1.54%
Biotechnology	0.00	0.33	0.00%	0.09%
Materials, metallurgy	1.95	0.38	0.44%	0.10%
Agriculture, food chemistry	0.06	0.17	0.01%	0.05%
Basic materials chemistry	10.89	9.92	2.44%	2.68%
Chemical engineering	1.06	2.96	0.24%	0.80%
Surface technology	2.67	0.04	0.60%	0.01%
Materials processing	3.28	0.67	0.73%	0.18%
Thermal processes	0.29	0.00	0.06%	0.00%
Environmental technology	3.00	0.00	0.67%	0.00%
Machine tools	1.55	0.04	0.35%	0.01%
Engines, pumps, turbines	18.53	4.00	4.15%	1.08%
Mechanical elements	1.77	0.17	0.40%	0.05%
Handling, printing	15.90	13.96	3.56%	3.77%
Food processing	0.33	0.13	0.07%	0.03%
Transport	12.89	7.13	2.89%	1.92%
Nuclear engineering	0.80	0.21	0.18%	0.06%
Space technology	0.00	0.00	0.00%	0.00%
Consumer goods	0.58	0.25	0.13%	0.07%
Civil engineering	0.00	0.08	0.00%	0.02%

German patent system. Having a higher concentration of patents in one technology field seems to support the formation of triples due to a higher likelihood of multiple blocking relationships between large patent applicants. However, since the two indicators of concentration measure the distribution of patents among patentees and do not consider the overlap between the patents, they are hard to compare directly to the triples indicator.

4. Cross-system differences in patent density

To analyze differences in patent density between different patent systems, we calculate the triples for the U.S., the German, and the EPO patent systems based on the modified algorithm. It is clear that these jurisdictions are also different in terms of numbers of patent applications in different technology fields and show differences in general citation styles that again influence the number of triples detected. For example, our data show that U.S. patents, on average, cite more patents than do German patents. Furthermore, U.S. patents cite a smaller share of non-domestic patents than do German patents. Hence, to provide a less biased measure for the patent density in different patent systems we calculated the number of triples normalized by the total number of backward citations to patents within the same patent system in the respective technology field. For our analysis of differences in patent density, we include patent applications between 1980 and 2005 at the respective patent office based on data from the EPO Worldwide Patent Statistical Database (PATSTAT) as of April 2009, which includes data for all three jurisdictions.

Fig. 4 shows the share of triples per technology field by jurisdiction. Again, Table 3 lists the five technology fields with the most triples for each jurisdiction. Interpreting the share of backward references normalized triples in each technology field, we find that the U.S. and the EPO patent system are most dense in the technology fields of semiconductors, telecommunications, information technology, audiovisual technology, and optics, while in the German patent system transportation, engines and pumps, control technology, and mechanical elements dominate. Testing for differences between the distribution of triples normalized by backward references we find no statistically significant differences between the U.S. and the EPO patent system ($\chi^2 = 33.91$, $df = 29$, $p > 0.1$), while we clearly find such differences between those two systems and the German patent system.

Going beyond the mere distribution of density across technology fields, our data also gives insight into the development of patent thickets per jurisdiction over time (Fig. 5). We observe an increase in patent density in all three patent systems between 1980 and 2002. The decreases in patent density observed in the last three years should be due to lags in the examination processes. Differences in grant lags can also partially explain slightly different peaks per patent system. We see a peak in 2001 for EPO and USPTO and a peak in 2002 for the German patent system. Harhoff and Wagner (2009) report a 52 months' time lag at the EPO while Popp et al. (2004) report more than 31 months for the USPTO. Our own data confirm that USPTO has the shortest grant lag, followed by EPO and DPMA. However, we cannot explain why before 1992 the patent density grew faster in the EPO patent system than in the U.S. and German systems, but grew slower since then. More research is needed to more fully understand this difference in growth rate.

5. Discussion

This article analyzed differences in the density of patent thickets in the U.S., German, and EPO-governed patent systems. We found that the U.S. and the EPO patent systems show similar patterns in patent density across technology fields, while the German patent system exhibits a deviating pattern.

5.1. Implications for theory

In the German patent system the traditional strong technology fields that are related to the automotive industry and mechanical engineering are much denser than in the other patent systems. These findings might seem surprising since the EPO patent system and the German patent system cover similar geographical regions. Furthermore, these two systems are similar to each other in that they do not require the patent applicant to list prior art. Two potential explanations exist for this phenomenon. First, the type of innovations patented in a patent system can create differences in patent density. German innovators focus highly on innovations in the fields of mechanical engineering and automotive. Such high focus can lead to technology clusters and races among close innovators working in these fields, both of which factors increase the probability that high overlap among patents of different patent holders will emerge. This explanation is in line with von Graevenitz et al. (2013) who find that lower technological opportunity and higher competition in complex technology fields leads to growth of patent thickets. It is also in line with a more general strand of literature documenting an S-curve effect in patent applications over

Table 2
Triples indicator and concentration indices for technology fields with highest overlap in the different patent systems (1980–2008).

Technology field	Absolute number of triples (rank)	Triples normalized by 1,000 patent applications in the technology field (rank)	Triples normalized by 1,000 patent backward references (rank)	Triples normalized by 100 applicants in the technology field (rank)	Herfindahl index of applicants (rank)	Share of top four applicants (rank)
EPO						
Audiovisual technology	2,628 (1)	31.8 (1)	10.3 (1)	27.8 (1)	186.6 (1)	23.3% (1)
Telecommunications	2,379 (2)	17.5 (2)	8.5 (2)	20.9 (2)	131.0 (3)	16.2% (4)
Information Technology	1,574 (3)	13.0 (3)	6.6 (3)	8.6 (4)	87.5 (9)	13.0% (9)
Semiconductors	535 (5)	11.9 (4)	4.1 (4)	12.8 (3)	101.8 (6)	13.2% (8)
Optics	574 (4)	7.4 (5)	2.0 (5)	6.8 (5)	103.4 (5)	15.6% (5)
Basic materials chemistry	252 (9)	4.2 (6)	1.3 (6)	2.9 (7)	125.2 (4)	18.8% (3)
Macromolecular chemistry…	292 (7)	3.8 (7)	1.3 (7)	4.4 (6)	87.7 (8)	14.0% (7)
Engines, pumps, turbines	207 (10)	3.3 (8)	0.9 (8)	2.1 (8)	100.5 (7)	15.5% (6)
Handling, printing	346 (6)	3.1 (9)	0.8 (9)	1.3 (9)	30.7 (15)	7.8% (15)
Transport	267 (8)	2.4 (10)	0.6 (10)	1.3 (10)	31.8 (13)	6.8% (17)
USPTO						
Semiconductors	132,233 (3)	652.1 (1)	74.4 (1)	1,632.3 (1)	139.7 (3)	16.4% (5)
Telecommunications	164,660 (2)	493.8 (2)	69.9 (2)	847.5 (2)	80.9 (7)	12.0% (8)
Information Technology	239,913 (1)	462.4 (3)	62.0 (3)	783.7 (3)	170.5 (1)	19.2% (2)
Audiovisual technology	88,360 (4)	379.8 (4)	52.5 (4)	550.4 (4)	136.7 (4)	18.5% (3)
Optics	61,524 (5)	263.9 (5)	29.8 (5)	410.9 (5)	129.2 (5)	17.4% (4)
Electrical engineering	40,286 (6)	142.2 (6)	17.3 (6)	131.5 (6)	35.3 (14)	7.2% (15)
Engines, pumps, turbines	15,500 (9)	134.6 (7)	14.2 (7)	104.8 (7)	85.7 (6)	14.3% (6)
Control technology	39,774 (7)	115.5 (8)	13.6 (8)	84.3 (8)	17.2 (22)	4.6% (24)
Transport	22,740 (8)	110.4 (9)	10.9 (9)	66.3 (10)	36.2 (13)	9.1% (12)
Handling, printing	14,689 (10)	69.0 (10)	6.9 (10)	40.6 (11)	49.4 (11)	10.1% (11)
DPMA						
Transport	3,040 (1)	12.2 (1)	7.3 (1)	14.6 (1)	48.3 (10)	10.9% (10)
Engines, pumps, turbines	624 (2)	5.2 (2)	3.4 (2)	6.4 (2)	145.9 (3)	16.9% (4)
Mechanical elements	232 (4)	1.7 (3)	1.0 (3)	1.5 (3)	23.0 (16)	6.6% (16)
Control technology	265 (3)	1.3 (4)	0.9 (4)	0.8 (5)	41.2 (11)	9.6% (11)
Electrical engineering	186 (5)	1.0 (5)	0.7 (5)	1.0 (4)	88.9 (8)	13.1% (8)
Telecommunications	61 (7)	0.5 (7)	0.6 (6)	0.5 (6)	169.4 (2)	18.2% (3)
Environmental technology	21 (10)	0.8 (6)	0.6 (7)	0.3 (8)	24.3 (14)	6.7% (15)
Handling, printing	85 (6)	0.4 (8)	0.4 (8)	0.3 (9)	25.9 (12)	7.8% (12)
Semiconductors	20 (11)	0.4 (9)	0.3 (9)	0.5 (7)	173.3 (1)	20.9% (1)
Information Technology	16 (14)	0.2 (13)	0.3 (10)	0.1 (17)	108.5 (6)	15.4% (7)

the technology lifecycle resulting in particular dense patent spaces for mature technologies (Achilladelis, 1993; Haupt et al., 2007; Munari and Toschi, 2014).

Second, differences in examination and, hence, citation practice among patent systems might yield differences in patent density. To test if differences in examination/citation practice matter we sought to rule out differences in innovations by only including innovations patented (1) in Germany, (2) at the same time in one of the other two jurisdictions, and (3) in both other jurisdictions, respectively. We then calculated triples for these restricted samples. However, the resulting datasets were too small to identify a relevant number triples even for the two systems case. For the combination DPMA and EPO, we obtain no triples, for DPMA and USPTO two triples, and for DPMA, EPO, and USPTO no triples. As a less restrictive test, we tried to calculate triples only for applicants active in two jurisdictions that faced the same problem of too restricted data. Hence, with the data at hand we cannot disentangle which effect—differences in innovation or examination/citation practice—matters in explaining observed differences in patent thickets. More research is definitely warranted on this phenomenon.

5.2. Implications for management

For management practice, our results imply that firms have to adapt their strategies for navigating patent thickets to the particular markets in which they operate. A firm's intellectual property (IP) strategy is thus not only contingent on the technology fields but also on the different national markets. So far literature on international IP strategies had identified different competitive situations in national markets and differences in the strength of the IP right regime (Huang and Jakob, 2014) that have to be taken into account shaping an international IP strategy. This article makes clear that also the different patent density in all relevant national markets have to be taken into account. Hence, even regarding the same product extensive cross-licensing might be more relevant in one

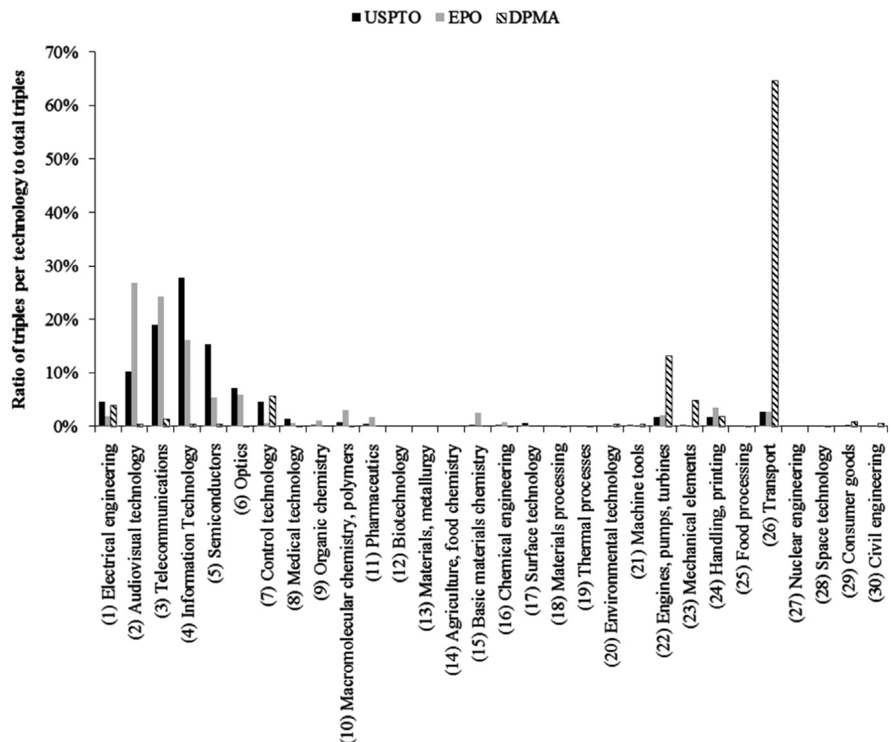

Fig. 4. Comparison of the share of triples per technology field in different patent systems (1980–2005).

Table 3
Comparison of the share of triples per technology field in different patent systems (1980–2005) (Fig. 4).

Technology field	USPTO	EPO	DPMA
Electrical engineering	4.7%	1.9%	4.0%
Audiovisual technology	10.2%	26.9%	0.4%
Telecommunications	19.0%	24.3%	1.3%
Information Technology	27.7%	16.1%	0.3%
Semiconductors	15.3%	5.5%	0.4%
Optics	7.1%	5.9%	0.3%
Control technology	4.6%	0.6%	5.6%
Medical technology	1.4%	0.6%	0.1%
Organic chemistry	0.3%	1.1%	0.0%
Macromolecular chemistry, polymers	0.8%	3.0%	0.0%
Pharmaceutics	0.5%	1.7%	0.0%
Biotechnology	0.0%	0.1%	0.0%
Materials, metallurgy	0.0%	0.1%	0.0%
Agriculture, food chemistry	0.0%	0.1%	0.0%
Basic materials chemistry	0.2%	2.6%	0.0%
Chemical engineering	0.3%	0.7%	0.1%
Surface technology	0.5%	0.0%	0.0%
Materials processing	0.1%	0.2%	0.2%
Thermal processes	0.0%	0.0%	0.2%
Environmental technology	0.1%	0.0%	0.4%
Machine tools	0.3%	0.0%	0.4%
Engines, pumps, turbines	1.8%	2.1%	13.3%
Mechanical elements	0.3%	0.1%	4.9%
Handling, printing	1.7%	3.5%	1.8%
Food processing	0.0%	0.1%	0.0%
Transport	2.6%	2.7%	64.7%
Nuclear engineering	0.1%	0.1%	0.0%
Space technology	0.0%	0.0%	0.1%
Consumer goods	0.2%	0.3%	0.8%
Civil engineering	0.1%	0.0%	0.6%

national market than for the other. For multinational firms, this adds to the managerial complexity of navigating patent thickets in a most efficient way and, more generally, makes the identification of a highly efficient international IP strategy a challenging task.

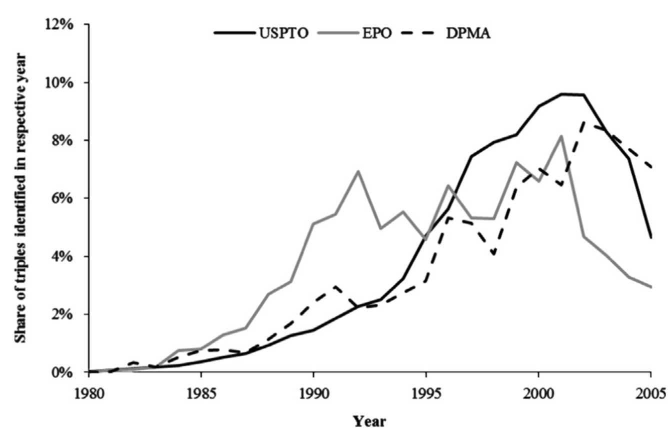

Fig. 5. Development of patent density over time measured by the modified triples algorithm based on patents issued by USPTO, EPO, and DPMA.

5.3. Implications for policy

Our study contributes to the ongoing debate about redesigning patent systems to diminish resulting frictions. We provide evidence that relative patent density of technology fields is comparable between the USPTO and the EPO systems. This is an important contribution to existing literature as research on patent thickets among U.S. and European scholars mostly implicitly assumes that patent thickets lie in the same technology fields. However, we are also first to provide evidence that not all patent systems show a similar relative patent density of technology fields by highlighting the density pattern of the German patent system. Differences in the patent density of several patent systems imply that policy measures to disentangle patent thickets on a patent system level will affect different industries in different jurisdictions. When the policy measures are discussed on an industry level, differences in the patent density between different patent systems have to be accounted for to target the right industries. German policy makers have to take the diverging patent density of their patent system into account when considering regulatory measures applied or discussed in other patent systems. The finding that patent thickets in Germany do not coincide with patent thickets in the EPO patent system is particularly interesting, since incentives to innovate in Germany are affected by regulators of both the EPO and the German patent systems. Both patent systems overlap since EPO patents for which coverage of the German market has been sought and German patents can both be enforced in German civil courts. The difference in density patterns we observe between these two patent systems also raises the question of whether scholars and regulators should analyze on the combined European patent systems (EPO), or whether they should focus on the country level and study all patents valid in each country separately. In general, further research is warranted to understand the interplay of overlapping patent systems in Europe; in particular, to understand the impact of this overlap on patent thickets faced by innovators on a country level.

6. Conclusion

This article highlighted that patent thickets—that are currently highly debated—do not necessarily coincide between all patent systems. Such differences in patent density in the same technology fields over different patent systems could provide interesting empirical test beds to study the effects of patent thickets on innovative activity. Also further research is warranted to understand why patent density has developed differently in some patent systems than in others.

Our study comes with some limitations that point to more avenues for further research. First, it relies on the EPO name standardization, which is a project by the EPO that corrects the numerous data errors in patentee names and strives to accurately assign patents to unique applicant identifiers. Although extant research also relied on the EPO applicant name consolidation (e.g. Harhoff and Wagner, 2009) there exists no evidence on its quality. However, as we build our study on a total of nine million patent applications, a new, manual correction was not feasible. Von Graevenitz et al. (2013) spent considerable resources in manual name cleaning of the patents applied for by the 1,000 top applicants at the EPO—the smallest patent system in terms of patent applications included in this study. This consolidation von Graevenitz et al. (2013) performed can also explain why they found more triples than did our modified algorithm. Second, there are differences in the citation data of the patent systems analyzed that we could not control for in this descriptive study. The most important difference is that in the United States, the patent applicant has to provide the patent office with information on prior art, while in Germany and in the EPO system the patent examiner does all the research. As the backward references on which we based our analysis result from these research reports, these differences may have introduced biases. However, it is neither clear in which direction such biases should work nor if they exist at all. To diminish potential biases, we compared only the relative patent density of technology fields in the analyzed patent systems. Third, we focused only on three patent systems. We did this, because we are familiar with all three systems and know that all ensure that our data is reliable. However, it would be instructive to learn what differences in patent density exist between other patent systems.

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