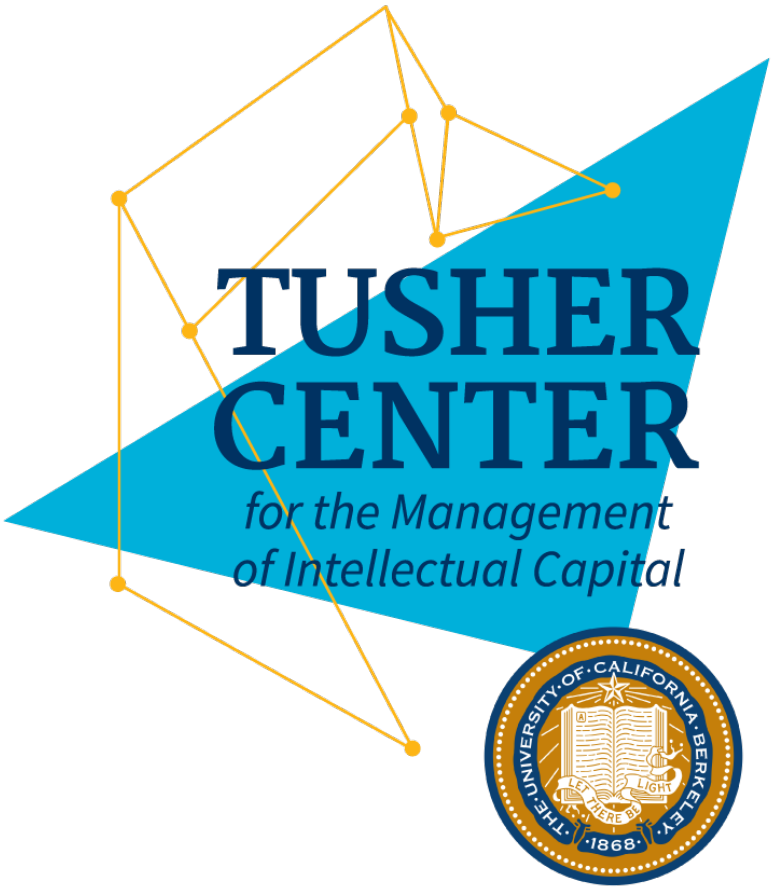

Untangling the Patent Thicket Literature

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Abstract

At least 164 papers have defined a ‘patent thicket’ since the first mention of the term in 1988. There is no canonical definition. Instead authors use the term to refer to various combinations of seven different underlying economic issues. An average paper in 2001 used a definition based on 1.2 of these issues, and the complexity of definitions grew by 35% over the following decade. This increase in definitional complexity is partly a response to a growing sophistication in the broader literature on the economics of patents. However, repeat authors are frequently inconsistent in their definitions, and overall there is evidence of a growing confusion concerning patent thickets. Our analysis largely resolves this confusion. It also suggests that ill-advised policy reform efforts, and not patent thickets themselves, threaten the health of the innovation economy.

1 INTRODUCTION

The last half century has seen an extraordinary amount of economic growth based on technological innovation. The nature of innovative goods and services changed during this period as new high-technology industries, involving complex products and cumulative innovation, gave rise to the modern information age. These industries, including semiconductors, communications, information technology, pharmaceuticals, and biotechnology all made extensive use of patents to protect their inventions. As a consequence, beginning in the 1980s, society witnessed a phenomenon that Jaffe (2000) and Hall (2004) labelled the 'patent explosion'.[2] Set in this context, concern over a potentially systematic failure of the patent system emerged. This concern is best known by the term *patent thickets*.

"The sky is not falling," says Jeffrey Lewis, President of the American Intellectual Property Law Association.[3] Although Lewis cogently makes the point that many of the arguments today concerning patent thickets played out in the sewing machine industry in the 1850's (see Mossoff, 2009), and suggests that such debate is "a natural part of the evolution of a complex, marketable and successful product", many industry experts, policy makers and academics do seem to behaving like Chicken Little.[4] In the last decade, patent thicket arguments have become a routine fixture in intellectual property court cases, and a staggering barrage of policy reports and recommendations have been commissioned on patent thickets by a wide variety of public bodies.[5] Moreover, a sizeable and fractious economic literature on patent thickets has developed.

Unfortunately, the patent thicket literature has failed to reach much in the way of firm conclusions. It is not so much contentious as confused. Individual papers provide individual results but collectively the literature lacks coherence.[6]

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[2] In the U.S. from 1900 to 1980, the number of patent applications ranged from around 50,000 to 100,000 per year. It then rose to over 450,000 per year by 2006. Hall et al. (2012) provides an informative diagram. In 2010 the time to prosecute a patent application at the U.S. Patent and Trademark Office (USPTO) was around three years. It is possible that this 'explosion' has now ended.

[3] www.wipo.int/wipo_magazine/en/2013/01/article_0002.html

[4] The folk tale classified as Aarne-Thompson-Uther 20C has culturally specific names. The tale is about a chicken who thinks the sky is falling after an acorn falls on his head.

[5] 16 of these reports are included in our review

[6] For example, papers contribute to patent ticket theory (e.g., Heller and Eisenberg, 1998; Shapiro, 2001), provide empirical evidence of strategic responses to hypothesized patent thicket problems (e.g., Ziedonis, 2004; Cockburn and MacGarvie, 2009 & 2011), claim to map the extent of patent thickets (e.g., Clarkson, 2004 & 2006; and Von Graevenitz et al. 2011), suggest that private arrangements mitigate any adverse effect of patent thickets (e.g., Evans

In order to assess the patent thicket literature's sources and areas of confusion, we survey 164 scholarly papers that define, or at least use in a codifiable way, the term "patent thicket". We believe that our sample covers almost the entire population of such papers over the literature's initial 23 years, from the first mention of the term 'patent thicket' in 1988 up until the end of 2011[7]. For each paper we examine the economic issue(s) implied in their definition. What we find is very unsatisfactory.

It turns out that there is no single canonical definition of a "patent thicket"; instead authors use the term to describe a number of different economic issues. These different issues have different policy implications and can be resolved by different private institutions and arrangements. However, almost all of these issues have something in common: in theory they could (albeit for different reasons) lead to economic inefficiency beyond that inherent in the patent system itself.

Accordingly, in this paper we seek to answer the following three questions: What economic issues (or "problems" or circumstances) are called patent thickets? How are these issues related in theory and in practice? And, with answers to the previous questions in hand, how would we characterize the state of the patent thicket literature?

We find that four distinct economic issues are present in 10% or more of the definitions in our sample; these are summarized in Table 1 below. Furthermore, on average across our sample, we find that a paper typically implements a definition consistent with 1.4 of these four economic issues. In some papers the identification of multiple issues is intentional.[8] However, in the majority of papers it arises from semantic ambiguity in the authors' stated definition.

We suggest that one reason why papers implement definitions that are consistent with more than one economic issue is that many of the original definitions of patent thickets were made by analogy. Analogies face the risk of multiple possible interpretations. Shapiro (2001) is frequently quoted in the literature saying that patent thickets are "a dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new

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and Layne-Ferrar, 2004), or report survey evidence to conclude emphatically that patent thickets either do not exist or do not have adverse welfare effects (Mann, 2004).

[7] Our sample suffers from truncation issues beyond 2011 because there is a lag in papers being recorded in some journal databases and in the search results of Google Scholar.

[8] Heller and Eisenberg (1998), for example, explicitly address two separate issues. de Russe et al. (2013), discussed in detail later, directly consider the definitional disarray in the patent thicket literature.

technology". Shapiro's analogy is compatible with all four of the most commonly discussed economic issues referred to as patent thickets.

Table 1: The four most common economic issues underlying definitions of patent thickets

Name	Basis of economic issue	Incidence
Diversely-held complementary inputs	**Coordination**: patent holders determine licensing rates independently	59%
Overlapping patents	**Imperfectly defined property rights**: wasteful duplication of licensing expenditure	46%
Gaming the patent system	**Moral hazard**: patent applicants take hidden action and impose costs on genuine innovators	21%
Saturated invention spaces	**Imperfect competition**: a small number of firms hold all possible patent rights in an area	11%

Patent thicket definitions are also becoming more complex over time. The number of economic issues consistent with a paper's definition has grown at an average rate of 0.02 per year from 2001 to 2011, and no single issue appears positioned to exemplify or epitomize the term 'patent thicket'. Both naïveté and sophistication help explain the increased variety of definitions in the patent thicket literature.

We note that the scholarly literature on the economics of patents has evolved contemporaneously with the patent thicket literature. We show that authors that use certain concepts from the broader literature are more likely to implement a definition that implicates a larger number of economic issues.[9]

However, the weight of our evidence is indicative of an increasing level of confusion in the literature. A paper's discipline, type (theory, empirical, or discussion), focal industry, and topic are collectively the strongest predictor of which issue will be highlighted in a definition. The theoretical relationships between economic issues, which we discuss in detail later, do not appear to materially affect issue use. The context of a paper therefore matters more than its theoretical

[9] These concepts included patent breadth, probabilistic patents, patent hold-up, strategic patenting, and licensing transaction costs

focus. The diversity of the context of the papers in our sample increases over time (likely as the real-world hysteria over patent thickets has intensified).

The literature is best characterized as waves of papers from disparate sub-literatures, with author knowledge confined by the boundaries of these sub-literatures.[10] Unfortunately, though, the sub-literature of 'core' papers – those directly concerned with developing patent thicket theory and/or providing empirical evidence on patent thicket effects – does not show evidence of moving towards a synthesis.[11]

Although our primary purpose is to document and explain the growing complexity in the patent thicket literature, we also endeavor to clarify it. The scholarly understanding of patent rights has matured considerably since the inception of the patent thicket literature. We briefly summarize many of this broader literature's advances in the next section. We then endeavor to leverage its progress to provide the patent thicket literature with foundation that is grounded in economics.

Finally, we argue that the intensity of the current policy debate on patent thickets is misplaced. Some scholars suggest that the rise of the high-technology industry has overburdened the patent system and caused a systematic failure. There are a number of economic circumstances that could, individually or in concert, cause such a failure, at least in theory. But there are also private and institutional arrangements that avert such a failure in practice. At present we have to say that the sky is not falling: All of the economic circumstances leading to patent thickets can only occur when an economy has rapid invention delivering substantial commercial benefits – this is a good economic problem that should be kept in its proper perspective.

The remainder of this paper is organized as follows. The next section provides a brief primer on the institutional details of patents and the patent system, and then summarizes the contemporary literature on the economics of patents. It defines modern terms like patent breath, probabilistic patents, hold-up, hold-out, strategic patenting, transaction costs, and search costs. We will use the incidence of these modern terms as a measure of scholarly sophistication. Section 3 describes

[10] For example, economic theory papers are largely concerned with the DHCI problem. They give rise to empirical papers that drift towards first including overlapping patents along with DHCI, and then begin abandoning the usage of DCHI. Intellectual property right reform papers appear largely oblivious to the DHCI problem and instead disproportionately favor an issue based on patent applicants gaming the patent system. And firm strategy papers begin by considering saturated invention spaces and then switch to overlapping patents as their issue of choice.

[11] Core papers with more authors and/or experienced authors do not use a statistically significantly greater number of issues, and repeat authors of core papers demonstrate mildly statistically significant inconsistency in their subsequent issue use.

the four most commonly used economic foundations for patent thickets found in the literature. We provide example quotations for each kind and explain their theoretical consequences. Section 4 provides details of our sample and data collection methodology, and Section 5 provides a meta-analysis of the literature. A discussion of the state of research and policy concerning patent thickets concludes.

2 THEORETICAL AND INSTITUTIONAL BACKGROUND

In this section, we provide a foundation for the economic issues identified in the patent thicket literature. We briefly discuss the neoclassical economic justification for patents, as well as some useful institutional details on patents and the patent system. We then summarize some key developments from modern literature the economics of patents.

2.1 Neoclassical economics and institutional detail

Innovation is associated with two neoclassical economic "problems" that complicate the allocation of resources in a market economy (see Nelson, 1959 and Arrow, 1962). First, innovation has positive externalities. Imitators can free-ride on an inventor's costly effort. Because private returns are less than social returns, there is under-investment in inventive activity. The patent system endeavors to correct this problem by allowing the inventor to capture (more of) the rents from their invention.

Second, invention and its commercialization lead to information problems. Disclosure of the invention allows (some of) the knowledge about it to be released into the public domain. Arrow's Paradox highlights that the disclosure of an idea or an invention is often necessary to establish its value but, absent contractual or property rights, disclosure results in its irreversible appropriation (see Arrow, 1962).

Patents are a particular kind of property right: they are potentially exclusionary rights. In return for disclosing the invention, the patent office grants the inventor the limited right to exclude others from using their invention for a certain period of time.[12] Thus, should the courts enforce patent rights, patents help ameliorate the problem of Arrow's Paradox.[13] Patent policy therefore

[12] In the U.S., prior to July 1995 this period was 17 years from grant; subsequently it became 20 years from application.
[13] So do confidentiality and non-use agreements; but their enforceability is often weak.

trades off reducing two sources of market failure – externalities and information problems – with an increase in imperfect competition, which arises as a court enforces the patent owner's rights.

Patents are made up of claims. Each claim should embody a distinct "inventive step" that is novel and non-obvious.[14] Taken together the claims should have "unity of invention" and the invention should be useful. A patent application is subject to review by a patent examiner. In theory, the examiner should review each claim and only grant claims that are novel, non-obvious, and useful. Patent filings are now typically disclosed to the public eighteen months after application.

Patents cannot be applied for until an invention is made and inventions can be used at any time. Once a patent is granted it can be licensed, infringed and litigated. Aside from post grant reviews, the patent office is no longer involved.

Processes surrounding patents are the domain of contracts and the courts. When a patent infringement suit is filed, the defendant can avoid damages if they can convince the court that either the patent is invalid or they have not made use of the patent's claimed inventive step(s). The defendant may also counter-sue for infringement of their own patents. Damages in patent infringement suits are limited to either the plaintiff's loss (lost profits or royalty) or the defendant's gain from infringement, unless the plaintiff can demonstrate that infringement was willful.[15] A successful claim of wilful infringement entitles the plaintiff to up to triple damages. When suits are matched with counter-suits, each anchored by important patents, litigation is often resolved with cross-licensing agreements, as well as a lump sum settlement payments.

The novel, non-obvious, and utility preconditions required to receive a patent grant are grounded in economics. Issuing patents doesn't incentivize innovation unless a new and non-obvious invention results. And the welfare gains from a new invention can only be realized if it translates into commercial or economic utility.

[14] Novel means that the inventive step should not have been disclosed before, in particular it should not be described in another patent or exist in the public domain. Non-obvious means that a person "skilled in the art" should not have thought, at the time of the patent application, that the inventive step was a combination of other pre-existing inventive steps or was otherwise obvious from the contemporary prior-art. In practice many claims do not embody an inventive step but instead set out, refine or extend exclusionary rights. See, for example, claims 11 & 12 of U.S. Patent 4,736,866.

[15] Lemley and Shapiro (2005) state that willful infringement occurs only when an infringer is aware of the patent and believes the patent is valid and that its conduct infringes.

2.2 The usage of patents

Under all current patent systems, the particular use of a patent does not need to be specified in its application. The indirect tie between the inventive steps in the technical claims and the usefulness of the entire patent subsequently achieved through another party's invention is the source of a claimed patent thicket problem. Kiley (1992) defines a patent thicket by saying: [16]

> *"Those operating at the beginnings of the road are most insistent on their right to nail down leverage that will remain formidable despite market place rejection of the uses to which they say their inventions may be put. The frank aim of these early stage workers is to control ultimate applications discovered by others."* -- Kiley (1992)

In essence, Kiley (1992) claims that applying for a patent based on an inventive step that does not have a clearly articulated stand-alone commercial value creates economic inefficiencies. But often it can be difficult to foresee which particular use of an invention will be profitable and which won't.[17] From an ex-ante (to the invention) perspective, economic policy wants innovators to see sufficient expected returns to incentivize sufficient investment in invention. Inventions that have larger potential commercialization opportunities will yield higher expected private returns, which will attract more investment in innovative activity, propelling faster and greater social value.[18]

Patents, contrary to widely-held opinion, seldom confer a monopoly. This is because a new commercialization opportunity attracts competitive invention to undermine it (see Mansfield, XXXX). Somaya (2003), Reitzig (2004), and others describe this phenomenon as the problem of "invent around". Rarely is it the case that a patent is so fundamental that one cannot invent around it, although sometimes the cost penalty and/or performance degradation is high. Moreover, patents are not self-enforcing and infringement is common. Fear of court awarded damages, or more likely a court enforced injunction, may dissuade infringers. But, as we will see later, the exertion of patent rights is probabilistic.

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[16] He illustrates this point with the story of NIH patent applications on partial cDNA fragments, derived from the human genome and sequenced under the direction of its employee, Dr. Craig Venter. Kiley quotes Dr. Venter as stating that "he still has no idea what it does."

[17] Viagra (sildenafil), for example, was originally developed to treat angina and hypertension, for which it was not particularly effective. It was only later found to be effective in treating erectile dysfunction.

[18] This is examined in the patent race literature. See Reinganum (1989) and the references therein.

Many inventions beget more inventions. There can be follow along patents on research tools (e.g., the Polymerase Chain Reaction and Cohen-Boyer gene splicing tools), many of which are used in combination to develop commercial products. And a patent can refine the functionality of a previous patent. The basic "Kilby patent" on the integrated circuit provides a well-known example of an upstream patent that has been refined by many subsequent downstream improvement patents.[19] When invention begets invention the inventor may need to devise a new business model to capture available value.[20] The patent exhaustion doctrine places constraints on where royalties may be assessed, though a patent owner is generally free to select where in the value chain to charge royalties.

2.3 Modern patent economics

Recent Coasian and neo-Williamsonian literatures on the economics of patents addresses the efficient allocation of rents from patentable invention. In this literature patents are imperfectly defined property rights, which are subject to contracting and bargaining problems, including hold-up and hold-out, as well as transaction and search costs.[21]

The patent office may make mistakes in the issue of some patents. Lemley (2000) references numerous sources before repeating the now stylized fact that a patent examiner spends, on average, just eighteen hours on a patent prosecution. He says: "It is not surprising, therefore, that PTO issues many patents that would have been rejected if the patent examiner possessed perfect knowledge."

There is a cost-benefit trade-off of reducing the uncertainty inherent in patents. Lemley (2000) argues the case of "rational ignorance at the patent office." He suggests that as many patent rights are never used, and as the uncertainty over rights only matters in a small number of cases, it is more efficient to have imperfect review by the patent office and then rely on the courts to

[19] U.S. Patent 3,138,743, filed by Texas Instruments on May 6th, 1959

[20] Owners of upstream patents may seek (and/or insist on) Reach-Through License Agreements (RTLAs) to allow them to capture some portion of the benefits of their inventions, as reflected in the fruits of downstream research. There are many real-world examples of RTLAs. These mostly occur in the fields of basic and biomedical research, and are common when firms collaborate with university researchers. RTLAs can be controversial as the license may afford contractual rights beyond the scope of the original upstream patent claim and/or the expiration of its exclusionary rights. "Post-expiration royalties" are sometimes cited as examples of patent misuse.

[21] Patents are imperfectly defined property rights in two ways: There is not a one-to-one mapping between their claimed (technological) inventive step(s) and their claimed exclusionary rights. And the both the specification and validity of a claimed inventive step, as well as the application of any claimed exclusionary rights, are always uncertain and subject to information problems.

resolve issues as they arise. However, difficulties identifying which inventive steps have been recorded in a patent application and which have actually been used to create an economic good or service, as well as uncertainty over the interpretation of patents under the doctrine of equivalents, still make any application of patent rights uncertain. And, of course, patents often cover inventions with uncertain values from their future usage.

There are also information problems inherent in patent rights. The codification of technical knowledge into a patent claim is imperfect, so the invention is better understood by the inventor than outsiders.[22] The patentee (and their lawyers) may know more about the patent's likelihood of validity than implementers, and infringers may know more about the likelihood of being found to have infringed than the patent-holder.[23] And a user of a patented technology, whether through assignment, license or infringement, may know more or less about the patent's value than its inventor.

Concepts like broad patents, probabilistic patents, patent hold-up, hold-out, strategic patenting, transaction costs, and search costs all draw from the idea that patents are imperfectly defined property rights that are traded in imperfect markets.

2.3.1 Patent breadth

The lack of a one-to-one mapping between an invention and its patent claims is an important theme in the patent thicket literature. In the broader literature on the economics of patents, Merges and Nelson (1990) introduced the concept of patent breadth. Under their definition, a broader patent covers more potential usages of the invention and so allows more claimed exclusionary rights. Other authors use the term patent breadth to indicate a patent claiming a great number of implicit inventive steps. Regardless, patent breadth is a function of how fundamental the inventive steps described in the patent will ultimately prove to be, the extent to which other adjacent inventive steps can yield the same economic usage, and the codification of the inventive steps into language.

Broad patents are not necessarily good or bad. The often reflect a fundamental innovation. In the context of cumulative innovation, Scotchmer (1991) argues that there are grave risks of

[22] The knowledge available from patents vs. inventors is sometimes referred to as know-how vs. show-how.
[23] This is especially true for process patents, as the processes used to make products often cannot be readily observed by others or "reverse engineered" by examining the product.

undercompensating inventors of foundational technologies, especially when a foundational technology has very little value on its own. This suggests that broad patents for fundamental patents can help address the under-funding problem that basic research exhibits.

2.3.2 Probabilistic patents

Likewise, uncertainty over patent rights also appears in both the patent thicket literature and adjacent literatures. Lemley and Shapiro (2005, 2006) emphasize that patents are 'probabilistic'. They suggest that "there is no way to determine with certainty whether the patent is valid and infringed without litigating to judgment." Enforcement of patent rights - observing and redressing infringement of patent claims - is therefore both costly and uncertainty. Bessen (2003) makes probabilistic patents the foundation of his rather unusual definition of a patent thicket:

> *"[P]atent thickets can reduce R&D incentives … patent infringement and validity are uncertain. A single patent does not convey certain monopoly rights, rather each patent provides a positive, but less than certain probability of winning an infringement suit. This means that the more patents a firm has related to a given product, the greater the joint probability of prevailing at trial."* – Bessen (2003)

2.3.3 Patent hold-up

Using probabilistic patents as a foundation, Skitol (2005), Lemley and Shapiro (2006), Lemley (2007), Farrell et al. (2007), Shapiro (2010), and others have advanced a small and highly controversial literature on "patent hold-up". This literature considers the allocation of rents between an infringer and a patent holder, usually in the context of Standard Essential Patents (SEPs) and Fair/Reasonable And Non-Discriminatory (FRAND) licensing agreements.

The Federal Trade Commission (2011) provides the following definition of patent hold-up: "'Hold-up' describe[s] a patentee's ability to extract a higher license fee after an accused infringer has sunk costs into implementing the patented technology than the patentee could have obtained at the time of [the accused infringer's] design decisions." However, some recent papers have stressed the obvious diametrically opposite problem. Langus et al. (2013), for example, point out that "the licensee may often engage in a reverse hold up". Reverse patent hold-up, loosely put, is where the accused infringer extracts zero (via infringing) license fee after the patent owner has sunk costs in developing the patented technology and alleged infringement has

taken place.[24] Again, this occurs as patents are not self-enforcing. Implementers can simply use the invention covered by a patent and wait to get sued, using as many diversionary tactics in the courts as is possible, knowing that it is hard, time-consuming, and expensive for a patentee to get an injunction. The judicial system is far from perfect; the patentee has few remedies absent a courts intervention.

The literature on hold up is bereft of any normative criterion for saying what the appropriate level of a royalty rate should be, even in the context of Standard Essential Patents (SEPs). All it can say is that the negotiated royalties have some chance of being higher following the creation of a standard.

Whether or not patent hold-up has been observed is contentious, as is the question of whether if it were to occur it would induce economic inefficiencies and the misallocation of resources. Epstein et al. (2012) note that guile is central to the definition of hold-up first laid out by Williamson (1971, 1979, 1985). They point out that there is no guile in the patent hold-up definition given by authors like Farrel, Hayes, Shapiro, and Sullivan, or in that given by the FTC.[25] Put differently, many authors are misusing or misapplying the original Williamsonian definition of hold-up. In Williamson's TCE paradigm, under-investment in relation-specific assets from the anticipation of hold-up can cause economic inefficiency, but efficiency is typically resolved by private orderings. However, the analysis is complicated if hold-up affects the return to innovation. Social and private returns to innovation depend upon one another. While royalties from patent hold-up are mere transfer payments, the loss of royalties to the inventor from the infringer disincentivizes inventive activity with high social returns.

2.3.4 Hold-out and strategic patenting

Hold-out can occur in the context of multilateral bargaining, for example when different products can be made out of different, diversely-held patented technologies. Farrell (2009) explains that

[24] Reverse patent hold-up is sometimes called "hold-out" by legal practitioners.

[25] Some authors implicitly allege guile when the patentee has signed a FRAND licensing pledge and then demands a higher than ex-ante licensing rate from infringers. If FRAND commitments were to restrict the post-infringement licensing rates to ex-ante levels this would induce infringement, which is economically inefficient. Other authors allege guile in reverse patent hold-up from the infringement of the patent. If the firm engages in non-market strategy and sponsors policy to reduce the licensing rates paid by infringers, then this would meet the definition of Williamson hold-up. On the other hand if infringement is accompanied by a demand of ex-ante licensing rates then this may not constitute guile and may be just an honest interpretation of FRAND.

when a partial agreement benefits the "nonparticipating (holdout) player", self-interest and social welfare may not be aligned.

Strategic patenting is sometimes defined as accumulating patents merely to achieve design freedom. These patents can be used as bargaining chips, rather than for their intrinsic value, and as such are largely welfare neutral, except in conjunction with transaction costs and cross-licensing agreements (discussed shortly). Much of the discussion of strategic patents takes place in the context of the patent thicket literature.

> *"To obtain the rights to infringe patents held by external parties and to improve their leverage in negotiations with other patent owners, these firms amass larger patent portfolios of their own with which to trade."* – Hall and Ziedonis (2001)

2.3.5 Transaction and search costs

Transaction and search costs have been central to Coasian economics since its beginning.[26] All patent-based interactions, from application to licensing to litigation, are subject to transaction and search costs. The inefficiencies brought about by these costs are generally straight-forward. For example, transaction costs can be a source of inefficiency when potentially beneficial transactions simply don't happen. However, some transaction and search cost issues concern perverse incentives and/or are artifacts of patent thicket issues; these bear brief discussion.

Patent applications are subject to transaction costs in the form of prosecution costs and renewal ('maintenance') fees.[27] These costs and fees are supposed to de-incentivize low value patents. However, they may also de-incentivize invention by small firms and individuals. The Leahy-Smith America Invents Act, 2011, contained provisions designed to ameliorate this problem. Likewise, searching for relevant patents may impose material costs. Wang (2010) argues that this may be particularly burdensome for new entrants who need to develop suitable search capabilities. On the other hand, the threat of a charge of willful infringement incentivizes firms to curtail any search for relevant patented prior art. If a firm is unaware of infringement, it can't be held willful.

[26] See Coase (1960).

[27] Prosecution costs, including application fees, search fees, legal costs, and other costs, are typically around $20,000. Renewal fees are currently $1,600 at 3.5 years, $3,600 at 7.5 years, and $7,400 at 11.5 years. There are currently discounted fees from the USPTO available to small entity and micro entity patent applicants.

In patent intensive, high-technology industries that make and use complex products – those associated with patent thickets - search and transaction costs may cause additional economic inefficiencies. Lemley and Shapiro (2006), Callaway (2008), and others discuss the volume of patented inputs required in complex products – estimates ranging from a hundred to several thousand patents are common.[28] Accordingly, Farrell (2009) observes that producers might not know with whom they must negotiate concerning patents. Farrell (2009) refers to this as a "potential patent thicket."

Likewise, complex products may also imply that producers must deal with many patent-holders, which is a characteristic of several different patent thicket issues. Transaction costs may then increase exponentially, as a firm must both secure more licenses and coordinate and bargain across licensors.

> *"One salient feature of patent thickets is the potential for higher costs associated with negotiating with many parties. To the extent that there are fixed costs of conducting a negotiation, having to deal with more parties will drive up costs of obtaining licenses. There may also be transactions costs associated with bargaining and coordinating negotiations with multiple licensors."* – Cockburn and MacGarvie (2011)

Furthermore, complex product industries make extensive use of cross-licensing agreements and Mexican standoffs (in essence mutual infringement and forbearance of litigation, discussed later). Cross-licensing agreements that license future inventions, as well as current portfolios, may reduce transaction costs. Mexican standoffs incur no transaction costs as long as they last. However, entrants may not possess a patent portfolio with which to cross-license or standoff incumbents (c.f. strategic patents). They would then have to incur transaction costs that an incumbent may not face, which in turn may deter entry. Cockburn and MacGarvie (2009) describes this circumstance as a patent thicket:

> *"However, it may not be just the absolute number of patents in an area that can deter entry, but also the extent to which those patents form a 'thicket' in the sense of generating transactions costs above and beyond simple blocking power."* – Cockburn and MacGarvie (2009)

[28] As a point of comparison, Goodman and Myers (2005) report that 7,796 patents were declared essential to two standardized third-generation cellular phone technologies.

3 FOUR PATENT THICKET DEFINITIONS

In this section, we discuss the economic issues behind the four most commonly-used definitions of a patent thicket in the literature. We then explore the theoretical commonalities and differences between these issues and relate them to the concepts just discussed from the literature on the economics of patents.

3.1 Saturated invention spaces

The earliest definition of a patent thicket that we found is in Teece (1998), who points out a simple issue with patents. We refer to this as 'saturated invention spaces' and describe it as when a single firm, or a small number of firms, successfully patents an entire technological area.

> *"The best initial design concepts often turn out to be hopelessly wrong, but if the innovator possesses an impenetrable thicket of patents, or simply has technology that is difficult to copy, then the market may well afford the innovator the time necessary to find the right design."* – Teece (1988)

Teece (1998) suggests that firms developing new technological innovations may have to saturate an invention space with patents to succeed. In essence, he points out a straight-forward extension to the neoclassical economic foundation of patents: When imitators can free-ride on an inventor's costly effort and obtain adjacent patents, a single patent may confer too little protection to incentivize innovation.

On the other hand, many adjacent patents create even more imperfect competition than a single patent. This is true whether adjacent patents are substitutes or complements to the original patent, as in Somaya (2003) and Hemphill (2003), respectively.

> *"Thickets of patents may be necessary to foil attempts to invent around the patent, and obtain a robust patent position."* – Somaya (2003)

> *"To forestall imitative activity and strengthen patent rights, firms often attempt to create a 'patent thicket'... obtaining patents not just on one central product or process, but on a host of related products or processes."* – Hemphill (2003)

As with single patents, a greater promise of rents in an area attracts greater investment in inventive activities. However, saturated invention spaces also have an indirect efficiency

considerations: First, having a patent may lower the costs of obtaining rival patents. This can be good or bad. A patentee may face lower costs of discovery for adjacent inventions as it is likely to have R&D resources specialized to a patent's technological area. A reduced R&D cost supports patenting of inventions that confer lower economic benefits. This concept is reflected in the quote from Hussinger (2006) below.

> *"A further development is that patents gained in value by their ability to be linked with other patents, which encourages patenting of marginal inventions. The resulting complex network of single patents ... was given the name 'patent thicket'"* – Hussinger (2006)

Second, after a patentee's first invention, there is a sense in which any race for adjacent patents is stacked in their favor: a patentee is likely to have informational advantages over its rivals because patents imperfectly disclose knowledge about inventions.

Overall, what matters is whether innovators remain undercompensated or might be over-compensated, at the expense of long-run competition and long-run economic welfare, when they acquire an entire thicket. Nordhaus (2004) estimates that innovators capture around 2.2% of the social return to innovation, which suggests that innovators are not over-compensated.[29] But whether there is over compensation with this type of thicket remains an open empirical question.

3.2 Diversely-held Complementary Inputs

When diversely-held patented components are complementary inputs into a product an economic inefficiency can arise through the lack of coordination of licensing prices. This issue is the most common basis for the definition of a patent thicket.

The description of a diversely-held complementary input (DHCI) patent thicket was first introduced in the law literature by Heller and Eisenberg (1998) as an example of the anti-commons problem (see Heller 1997) as applied to intellectual property rights:

> *"The tragedy of the anticommons refers to the more complex obstacles that arise when a user needs access to multiple patented inputs to create a single useful product*." - Heller and Eisenberg (1998)

[29] Nordhaus covers the period 1959-2001 and does not provide estimates for complex vs. non-complex products. Mansfield (XXXX) suggests that social returns to innovation are around 20 times the private return.

However, Shapiro (2001) subsequently formalized this notion and remains the most cited definitional referent for both it and the term patent thicket more generally.

> *"In order to produce [its product] as designed, the company needs to obtain licenses from a number, call it N, of separate rights holders... This situation is precisely the classic complements problem originally studied by Cournot in 1838... The well-known costs of static monopoly power are magnified: prices are well above marginal costs, causing inefficiently low use of these products."* – Shapiro (2001)

This post-invention theoretical problem has three necessary parts: 1) products require complementary patented inputs; 2) these inputs are diversely-held (i.e. held by N patent-holders); and 3) patent-holders set their license prices independently. The economic intuition is that the patent-holders are each caught in a Prisoner's Dilemma. The joint-profit and welfare maximizing royalties are ones that sum (in conjunction with any assembly cost) to give a single monopoly mark-up. However, this cooperative solution is unstable - each patent-holder has an incentive to defect. When a patent-holder achieves an increase in their royalty, it gets an additional benefit from the increased royalty rate and suffers only a fraction of the loss (providing $N > 1$) from the resulting decrease in demand for the final product. The rest of the loss is distributed as a negative pecuniary externality on the other patent-holders. [30]

The Cournot complements (non-cooperative) equilibrium is achieved when any further increase in individual license prices generates a more than equal offset in demand. In a simple model with competitive assembly the final markup on the product is N times the standard monopoly mark-up. DHCI therefore has the potential to cause static economic inefficiencies: the quantity of the product sold, the usage of the patent rights that the product relies upon, and the rents to innovation could all be drastically reduced.

Normally though, there are substitutes for complementary components because invent-around is commonplace. Theoretically, if components could be licensed separately (rather than through portfolios) and transaction costs were low, Bertrand competition should then result in the market

[30] A small minority of papers, all written by non-economists, assert that this problem is intentional "royalty stacking" (for a discussion of royalty stacking see Lemley and Shapiro, 2006). These papers claim that patent-holders would collectively want to charge as high a price as possible for their patents, implicitly confusing high prices with high profits. In fact, the opposite is true. The patent-holders would each be better off if they could coordinate their pricing decisions, reduce their royalties to the cooperative rates, and price so as to jointly create a single monopoly mark-up.

for the provision of components. This would undo the need for coordination. Although Bertrand competition among providers of patented components is seldom mentioned in the patent thicket literature, it is central to the adjacent patent hold-up literature (see Lemley and Shapiro, 2006).

3.2.1 Institutions and arrangements to mitigate the DHCI issue

Arrow (1973) notes that a greater joint payoff from cooperation incentivizes the creation of social institutions to facilitate cooperation. There is no shortage of institutions to resolve DHCI's coordination issue.

First there are individual arrangements, like reputations and credible commitments. Reputations work in the context of repeated interactions. Credible commitments may take the form of standardized licensing practices, including forward-licensing of future portfolios, and FRAND commitments. Standardized licensing practices can reduce transaction costs, but like FRAND commitments, may be susceptible to reverse patent hold-up.

Second, there are bilateral arrangements like cross-licensing and integration.[31] These can reduce transaction and search costs but they can also bring about imperfect competition (either directly or by creating barriers to entry - new entrants may lack strategic patents to secure a cross-license.) Moreover, these arrangements only work between firms that bring innovative products to market themselves. Innovators who specialize in invention, licensing out their commercialization, have no incentive to cross-license and integration would undo any benefits from their economic specialization.

And finally, there are multilateral arrangements, which also reduce search and transaction costs. Patent pools provide cooperative patent ownership. Patent pools are voluntary organizations that are often associated with Standard Setting Organizations (SSOs). Pools use numeric proportionality to assign licensing revenues.[32] Numeric proportionality can create adverse selection as it incentivizes patent-holders with valuable patents to keep them out of the pool.

[31] Integration includes mergers and acquisitions, as well as joint research ventures and other cooperative patent ownership.
[32] Using numeric proportionality may shield pools against charges of price fixing

Historically, pools have also suffered from imperfect competition - the sewing machine pool of the 1850's described in Mossoff (2009) contained substitute patents.[33]

Lemley (2008) documents that a common practice of implementers is simply to ignore patents, forcing the patent-holder to choose whether or not to sue. A Mexican standoff is when multiple patent-holders who are also infringers each independently decide not to sue each other over infringement. Mexican standoffs only work for innovators who self-commercialize their inventions – they do not work for innovators who specialize in invention and depend upon patent licensing (i.e., so called Non Practicing Entities or NPES). But when they work, the threat of willful infringement incentivizes a lack of search, which may make them more stable.[34] [35]

3.2.2 Private arrangements

Cheung (1969) argues that, absent transaction costs and other Coasian considerations, all institutional arrangements can achieve the same economic efficiency. However, as we have already seen, patents are rife with Coasian considerations.

The arrangements in place to mitigate the DHCI coordination issue are not economically equivalent to each other and in practice we observe usage of all of these arrangements. This strongly suggests that different arrangements best suit different purposes. These arrangements do breakdown and they do 'collide' – for example, industries like mobile telephony may have a mix of implementers engaging in Mexican standoffs and specialist inventors using credible commitments, perhaps with some firms stuck in between.[36] But these breakdowns and collisions spur new research and new arrangements. We see this as natural evolution of an intellectual property environment characterized by rapid, highly productive, complex innovation.

3.3 Overlapping patents

[33] Modern pools are required to submit notice to Anti-trust authorities for this reason. Nevertheless, concerns over patents receiving pool shares post-expiry remain pertinent today.

[34] Mexican standoffs are feasible during periods of incremental innovation, when market dynamics are reasonably stable. However, they can break down and result in a patent war when radical innovation changes the balance of power. The period of break down brings some Chicken Little hysteria but a new equilibrium, likely involving a new Mexican standoff, should result.

[35] The recent acquisitions of the Motorola Mobility patent portfolio by Google (to allow Android handset makers freedom to operate) and the Nortel Networks patent portfolio by the Rockstar Consortium (made up of the unlikely bedfellows of Apple, Microsoft, Ericsson, Sony, and RIM) provide examples of cooperative arrangements that may help maintain a Mexican standoff.

[36] This example collision may be the cause of many claims of patent hold-up, particularly in the context of standard essential patents, where a FRAND commitment can be subject to reinterpretation.

The second most common foundation for a patent thicket issue relies on overlapping patents. Patent overlaps can be horizontal (i.e. though patents that are largely adjacent to one another) or vertical (i.e. when patents are related through cumulative innovation). Horizontal overlaps arise because patent rights are imperfectly defined property rights.[37] They can result in a potentially wasteful duplication of resources.

Burk and Lemley (2003) provides an early example of a definition of a patent thicket based on horizontally overlapping patents:

> *"Closely related to the problem of complementarity is the problem of horizontal overlaps between patents. Patents are frequently broader than the products the inventors actually make. Multiple patents often cover the same ground, sometimes as an intentional result of the patent system and sometimes because patents regularly issue that are too broad or tread on the prior art."* – Burk and Lemley (2003)

Patents confer a potential right to exclude, not the right to use. Therefore if two or more patents cover the same technology, a user of the technology must take licenses to (or own) them all, or risk alternative claims of infringement. This could also be viewed as a wasteful duplication of expenditure, as well as a DHCI problem. When an implementer of a technology faces raised costs, the provision of the product embodying that technology will be reduced below efficient levels. Fortunately, overlapping patents can be addressed with many of the same arrangements as the DHCI problem.

When uncertainty (over infringement) is added to the mix, the wasteful expenditure issue can arise even if patents do not actually overlap provided that people believe that they do. This is apparent in Regibeau and Rockett (2011)'s definition of a patent thicket, which has its basis in the probabilistic patents framework:

> *"[A] firm with a valid patent covering a given aspect X of a new product might still fear that it might infringe another firm's patent that relates to the same aspect or at least to a*

[37] The notion of overlapping patents is an important contribution to our understanding of patents as imperfect property rights. This concept originated in the patent thicket literature and we strongly suspect that it stemmed from a misunderstanding. The word "overlapping" is used six times in Shapiro (2001): twice in section headers, once in each of the paper's two much quoted (but unfortunately analogous) textual definitions, and twice when referring to these definitions. Shapiro (2001)'s patents overlapped in the sense of multiple distinct patents bearing on a single end product.

> *similar underlying innovation. In such a situation, access to the other firm's patent is not technologically necessary but it is required if the firm wants to proceed under conditions of legal certainty."* – Regibeau and Rockett (2011)

Some papers discuss overlapping patents in the context of cumulative innovation. Refinement patents and research tool patents could result in vertically overlapping patent rights (or at least contractual rights). With vertical overlaps there is no sense of a wasteful expenditure, though there could still be a DHCI problem.

3.4 Gaming the patent system

There are information asymmetries between a patent applicant and the patent office and a patent applicant may take some inappropriate action, for example by applying for a patent that is not novel or is obvious. Such an inappropriate action can impose costs on the patent office and may generate negative externalities, imposing costs on genuine innovators. We refer to this situation as 'gaming the patent system'. The notion of gaming the patent system also appears in the highly-controversial literature on patents and non-producing entities (NPEs).

Although the action of applying for a patent is not hidden, at least from the patent office, the inappropriateness of a patent application can be. Gaming the patent system is therefore a type of moral hazard (see Marshall, 1976, for a discussion of moral hazard in insurance, and Holmstrom, 1979, for a discussion of it in principal-agent problems).[38] Gaming the patent system undermines its rationale and so would create economic inefficiencies.

Submarine patents provide a clear example of hidden action. Submarine patents are deliberately kept in their application stage, primary through the use of "continuations", so that their claims can be adjusted to cover new inventions or products.[39] Two papers in our sample, Hegde et al. (2009) and Rubinfeld and Maness (2004), define a patent thicket using submarine patents.

[38] Viewed through an alternative lens, this is also a form of Williamsonian hold-up. A patent is an incomplete contract between the firm and society. A patent applicant may engage in guile either during their application or during the enforcement of their granted patent rights. And a genuine innovator may make an investment that is, or at least can be deemed to be, specific to the applicant's patent rights.

[39] Subsequent to November 2000, most patent applications are disclosed by the USPTO 18 months after application. This makes submarine patents mainly of historical interest, as is now harder to keep their adjustment hidden from new innovators.

> *"[P]atentees file continuing applications to acquire patents with weak claims of dubious quality that were rejected by the examiner during initial prosecution. These lower-quality patents can be valuable to patent holders seeking to accumulate a thicket."* – Hegde et al. (2009)

In some contexts it is reasonable to ask whether a refinement patent truly embodies an inventive step that is novel and non-obvious given the prior art, and whether the patent applicant knew this at the time of the application. The practice of 'ever-greening' – effectively maintaining patent rights beyond expiration by applying for new patents on the same underlying technology – provides another example of hidden action. Jacob (2009) provides an example of a patent thicket definition that straddles (vertically) overlapping patents and ever-greening.

> *"Every patentee of a major invention is likely to come up with improvements and alleged improvements to his invention. By the time his main patent has expired there will be a thicket of patents intended to extend his monopoly."* – Jacob (2009)

However, most `gaming the patent system' thicket definitions discussed in the literature today are based on a more subtly stated undermining of the patent system. Economists and other scholars seldom allege outright inequitable conduct in patent applications. Instead they often tend to point out one of two symptoms that are strongly suggestive of hidden action.

The first, and generally more historic, problem concerns applying for patents on non-patentable subject matters, or at least subject matters that have (or may later) be determined to be non-patentable. Patents on software, business methods, and life forms have all received particular legal scrutiny concerning subject matter patentability.[40] At present, at least subject to some restrictions (see, for example, Association for Molecular Pathology v. Myriad Genetics, 569 U.S. 12-398, 2013), inventions pertaining to each of these subjects can be patented.

The second, and recently far more common, problem concerns patents of suspect validity. This issue has its practical roots in the patent explosion and draws its theoretical foundation from the probabilistic patents framework. When the number of patent applications increases and the resources of the patent office remain essentially unchanged, the patent office must spread its

[40] See Gottschalk v. Benson, 409 U.S. 63, 1972; State Street Bank and Trust Company v. Signature Financial Group, Inc., 149 F.3d 1368, Fed. Cir. 1998; and Diamond v. Chakrabarty, 447 U.S. 303, 1980, respectively.

examination efforts ever thinner. This could make obtaining a suspect patent easier, which in turn may incentivize applications for more suspect patents (see, for example, Jaffe and Lerner 2004). However, it is difficult, if not impossible, to distinguish between patents that later turn out to be invalid and patents that were obtained by through bad faith applications.[41] Many patent thicket authors therefore blame patent policy.

> *"The Patent Office has been awarding patents too easily and US courts have been too willing to uphold the validity of dubious patents. To the extent that patent policy inflates the number of patents that must be licensed in order to practice a standard, it contributes to what has been called a 'patent thicket'."* – Schmalensee (2009)

The need for strategic patents also incentivizes applicants to secure patents irrespective of their quality. Thus some solutions to the DHCI patent thicket, like cross-licensing and Mexican standoffs, may perversely exacerbate gaming of the patent system. In this context we see many other examples of suggestions of inappropriate patent applications.

> *"[One patent thicket] strategy usually involves acquiring a large quantity of often low quality patents, meaning those that are vague, likely invalid, or that provide narrow coverage of a feature having little commercial value."* – Federal Trade Commission (2011).

Overall, perhaps because bad faith is so hard to prove, there is little if any evidence that gaming the patent system is currently causing material economic inefficiencies. Nevertheless, this remains an important and legitimate policy concern.

> *"[T]here is surprisingly little empirical data to show that the patent thicket is subtracting from the rate of innovation... [but]... the quality of patent examination is scandalous. Even in Europe or North America, many dubious patents are issued."* – Attaran (2004)

3.5 Characteristics of patent thickets

[41] 'Win rate' data show that roughly 50% of patents are invalidated at trial. Some patents also appear, prima facie, to be spurious (see, for example, the incandescent lamp patent - 159 U.S. 465, 1895).or just silly (e.g., a crustless peanut butter and jelly sandwich patent: U.S. Patent 6,004,596). However, even Jerome Lemelson, who is alleged to have secured in excess of $1.3 billion in licensing revenues from submarine patents, was never found guilty of inequitable conduct (see U.S. District Court District of Nevada CV-S-01-701-PMP).

Each of the four most common patent thicket issues has two things in common: they each, at least in theory, have the potential to cause economic inefficiencies; and they each involve multiple patents. DHCI and overlapping patent thickets also require that patents are diversely-held, occur in complex product industries, and may be resolved by private arrangements. Saturated invention space and gaming the patent system may occur with a single patent-holder. [42]

Table 2: Seven economic issues labelled as patent thickets

Name (potential inefficiency)	Keywords, phrases and concepts
Saturated invention space (imperfect competition)	Terms like "cluster", "related", "adjacent", or "coherent group" to describe either patents or inventions. However, we also included several definitions that described patents as "minor" or "marginal" provided that there was no suggestion of bad faith
Diversely-held complementary inputs (coordination problem)	"Diversely-held" and "complementary inputs," or clear synonyms like "dispersed" or "fragmented" pertaining to ownership and "Cournot problem", "multiple marginalization", etc. in the context of licensing of patents held by multiple parties
Overlapping patents (wasteful duplication)	Any sense of patent overlaps including "overlapping claims" or "similar claims", and/or uncertainty over whether multiple patents may simultaneously be infringed
Gaming the patent system (moral hazard)	Primarily descriptions of patents as "questionable" "dubious" "bad", "likely invalid" and "junk," and phrases congruent with "impeding genuine innovators" or "rent-seeking activities", as well as other indications of bad faith
Transaction costs (transaction costs)	Cockburn & MacGarvie (2009, 2011), and others. Many more authors mention transaction costs in the context of patent thickets.
Probabilistic patents*	Bessen (2003) as a thicket definition. Ziedonis (2004), Siebert and Von Graevenitz (2010) and Regibeau and Rockett (2011) explicitly refer to the probabilistic patents framework.
Unspecified / extended use*	Kiley (1992)

* Probabilistic patents and Kiley (1992)'s unspecified/extended use do not have a clear theoretical reasons for causing inefficiency

In Table 2, below, we summarize all seven of the economic issues described as patent thickets that we found in the literature. We also provide examples of key words, phrases and concepts that we used to identify the four most commonly used issues, and example references for the others. Both transaction costs and probabilistic patents originate in the broader literature on the

[42] A single patent application might game the patent system but, the term 'thicket' is generally used in conjunction with a claim that suspect patents have become epidemic in a technological area.

economics of patents. They are much more typically used in conjunction with another patent thicket issue, and seldom seen as an issue in and of themselves. Accordingly, we treat them as 'modern terms' and use them to measure both the patent thicket literature's alignment to theory and its growing complexity. Kiley (1992)'s definition of a patent thicket stands alone, and does not appear associated with an economic inefficiency. We therefore discard it forthwith. Accordingly, we are left with the four main patent thicket issues for the focus of our analysis.

4 DATA AND METHODOLOGY

4.1 Sample collection

The aim of our literature review process was to locate, document and analyze as close to the population as possible of papers (published up until June 2013) that provide a definition of a patent thicket. We therefore built software that was capable of searching Google Scholar for keywords, retrieving papers, 'reading' papers using natural language processing, determining whether papers were relevant for potential inclusion in our sample, extracting references, and searching both forward and backwards citations again using Google scholar.[43,44] This software relied upon supervised learning; the supervision was provided by both trained research assistants and one of the co-authors. In some cases we were unable to find a copy of a candidate paper online. In these instances we contacted the authors and requested a copy.[45] Once we felt that we had achieved convergence –when no new papers were being found through keyword searches and/or forward or backward citations – we released our candidate list of papers to academics and practitioners and solicited additions.

Every paper that was included in our sample was read by a human expert and, although we used computer generated keyword counts for guidance, every patent thicket definition, contextual

[43] We also searched the Proquest, EBSCO, World of Science, and JSTOR journal repositories. However, we found that Google Scholar's coverage was vastly superior. Only a very few papers could be found using journal repositories that could not be found using Google Scholar (these papers are included in the sample), whereas the reverse is not true.

[44] There is a one year lag between a paper being published and it appearing in a journal database for some journals. Google may also suffer from a lag in indexing papers, or may take time to integrate meta-information about a paper into its search results. However, we feel confident that no papers directly about patent thickets have been missed and that our set of patents that mention patent thickets in other contexts closely approximates the population. We therefore claim to have the near-population of papers that provide a meaningful, independent definition of a patent thicket up until the end of 2011.

[45] We were unable to locate 3 papers but each of them appears to be a contribution to an out of print book or an unavailable conference proceeding.

attribute, and usage of a modern term was classified by a human expert too. This classification effort was undertaken in waves, until the final classification system used through-out this paper emerged.[46] In each wave, training was provided to two research assistants and classification was undertaken independently by the research assistants and one of the co-authors. The results were then analyzed for consistency. There was little disagreement over the final classification. We report the patent thicket issues and main contextual attributes of every paper in our final sample of 164 papers in the appendix.

4.2 An example classification of the economic issue(s) underlying a patent thicket definition

The 2013 European Patent Office (EPO) report 'Workshop on Patent Thickets' is authored by the EPO's Economic and Scientific Advisory Board, which is made up of a large number of repeat authors of papers on patent thickets.[47] One explicit purpose of the report was to put forward a comprehensive definition of a patent thicket. The reports says:

> *"[A] patent thicket usually involves (1) multiple patents on (2) the same, similar, or complementary technologies, (3) held by different parties, making it difficult to negotiate intellectual property rights (for example, licensing agreements) to the point where some scholars feel it might be socially inefficient."* – de Russe et al. (2013)

We classify this report's definition as consistent with DHCI, patent overlaps, and saturated invention spaces. DHCI is clearly apparent in "complementary technologies" that are "held by different parties". Invention spaces can be saturated by a single firm or a small number of firms, and from the context of the paper "similar patents" appears to refer to the foreclosure of adjacent inventions. And, as there was no allusion to inequitable conduct by patent applicants or patent-holders in the report, we classify multiple patents held by different parties on the same technology referred as consistent with overlapping patents and not with gaming the patent system. We agree with their statement that patent thickets are made up of multiple patents and have the potential to cause economic inefficiencies.

[46] We have presented the identification of economic issues underlying patent thicket definitions as a fait accompli for ease of exposition. In reality it emerged endogenously and other classification schemes may be possible.
[47] The Board was comprised of Bronwyn Hall, Sir Robin Jacob, Sadao Nagaoka, Geertui Van Overwalle, Dietmar Harhoff and others.

de Russe et al. (2013) also mentions transaction costs, search costs, probabilistic patents, and strategic patents in the context of patent thickets, as well as patent hold-up in the context of standard essential patents. As such the report provides the best attempt to tackle the definitional issues surrounding patent thickets in the literature.

4.3 Classifying contextual attributes

We define a paper's context as its publication type, paper type, topic, and focal industry. For publication type, each paper was categorized as belonging to just one of the following: economics, management, law, general science, or policy report. The classification was based on the nature of work undertaken in the paper, not by the authors' dominant focal discipline or by which journal it was published in, with the exception of policy reports which had to be commissioned by a recognizable and reputable entity like a patent office or the Federal Trade Commission. For paper type, topic, and focal industry, we recorded works as having a contextual attribute if they contained compatible research as a material component. For example, for paper type the eligible types were theory, empirical (including survey and measures), and discussion. A single paper could be marked with several such types (e.g., Galasso and Schankerman 2010 contains both theory and empirics).

Paper topics included firm strategy, private arrangements to facilitate patent transactions, Intellectual Property Right (IPR) reform, the effects of thickets on academic research, industry commentary, and, of course, patent thickets themselves. Firm strategy papers provide strategic advice to firms regarding their intellectual property – they discuss the strategic implications of blocking patents, pre-emptive patenting, secrecy, ever-greening, avoiding willful infringement, engaging in Mexican standoffs, and other defensive or offensive patenting behaviors, as well the consequences of doings so on collaboration, industry structure (including entry), and the value of firms. Private arrangement papers discuss cross-licensing, patent pools, patent clearinghouses, patent collectives, FRAND licensing agreements, patent intermediaries (including NPEs), shared platforms, technology standards, and Standard Setting Organizations (SSOs). IPR reform papers suggest reforms to the nature of intellectual property rights, examine processes for granting patents at the patent office, and advocate approaches to patent-related transactions for anti-trust authorities. A notable minority of papers were concerned with the effects of patent thickets on research done by academics. There was also a distinct set of publications that engaged in

industry commentary; commentary on the nanotechnology and genetics industries were particularly common.

Some papers are directly about patent thickets whereas others mention patent thickets while focusing on another topic. We will refer to papers directly about patent thickets as core papers. In the next section we will note that there are material differences between core and non-core papers, and so divide our sample in two sub-samples. We will then examine indications of learning between these two sub-samples, as well as within the core sub-sample.

Finally, we recorded whether a paper discussed one or more of three industry-type categories: 1) Basic research, which includes the commercialization of academic research, biotechnology, genetics, nanotechnology, and pharmaceuticals; 2) complex product industries, which includes information and communications technology (aside from software and the internet but specifically including semiconductors), manufacturing, and sewing machines (which in the period of analysis of papers discussing it was a complex cutting-edge product); and 3) an aggregate of firms focused on software, business methods, and the internet.

Generally in order for a paper to be coded as belonging to an industry it had to have at least a section of its analysis devoted to that industry. Most papers were marked with a single industry. It is worth noting that a very large number of industry commentary papers did not provide a codifiable thicket definition and so are not included in our sample. Our impression is that papers that discuss patent thickets without providing codifiable definitions are unclear on their semantics concerning patent thickets.

5 META-ANALYSIS OF THE PATENT THICKET LITERATURE

5.1 The (weak) manifestation of theoretical structure

The economic issues behind patent thicket definitions, and the modern terms from the broader literature, collectively have a theoretical structure. For example, DHCI and saturated invention spaces are have very different economic foundations, whereas DHCI and overlapping patents are much more similar and can be theoretically resolved by the same private arrangements. Likewise, probabilistic patents are central to several ways to game the patent system, important to overlapping patents and relevant to DHCI. They are less relevant in saturated invention spaces. In our first analysis we consider the co-occurrence of thicket issues and modern terms.

Our findings suggest that theoretical structure explains little of the practical usage of patent thicket issues.

Table 3: Co-occurrence of thicket issues and modern patent economics terms

The table describes the co-occurrence of thicket issues and modern terms. A paper's definition may be classified as consistent with multiple issues, so the number of papers does not sum to 164. We report log odds ratios of co-occurrence, with 2-sided Fisher exact tests used to calculate statistical significance. ***, **, and * denote significance at the 0.01, 0.05, and 0.1 levels, respectively.

	Papers	Economic concept	Log odds ratios of co-occurrence			
			DHCI	Overlap	Gaming	Saturated
Thicket issue	97 (59%)	DHCI	-			
	76 (46%)	Overlap	-1.2***	-		
	35 (21%)	Gaming the system	-0.6	0	-	
	18 (11%)	Saturated spaces	-1.4***	-0.8	0.4	-
Modern terms	4 (2%)	Probabilistic patents	N/A	1.3	1.3	N/A
	9 (5%)	Search costs	0.3	0	0	0.1
	54 (33%)	Transaction costs	1**	-0.5	-0.5	-1.4*
	29 (18%)	Patent hold-up	0.9*	0.1	0.1	-0.5
	22 (13%)	Strategic patenting	-0.2	1.3**	1.3**	0.8
	16 (10%)	Hold-out	1.2	-0.2	-0.2	0.2

In Table 3 we can see that only seven co-occurrences (out of a possible thirty) of issues and modern terminology in thicket definitions are statistically significant.[48] Moreover, we see a negative correlation between DHCI and overlapping patents, no relationship between probabilistic patents and gaming the patent system (or any other economic issue), and no

[48] An odds ratio is the most commonly used method to quantify how strongly some binary property is associated with another binary property. In our case it calculates the number of times we observe a definition consistent with both issues (or am issue and a modern term) multiplied by the number of times we observe a definition consistent with neither as a numerator, and the number of times we observe just one multiplied by the number times we observe just the other as a denominator. Log odds ratios are the natural logarithm of odds ratios. We report log odds ratios for ease of interpretation. We use 2-sided Fischer's exact tests to measure the statistical significance of the odds ratios of co-occurrence. Fischer's exact test is an exact test – the statistical significance is calculated exactly and its p-values are invariant to sample size.

relationship between strategic patenting and DHCI.[49] There are just two sets of relationships that do make theoretical sense: DHCI is associated with transaction costs and disassociated from saturated invention spaces, and strategic patenting is associated with both overlapping patents and gaming the system. Overall, there is little sense that theory is driving practice.

5.2 Contextual explanations for issue usage

There is some sense of two views of patent thickets in Table 3 – some authors discuss DHCI, don't generally discuss other issues, and do disproportionately use modern terms, whereas other authors discuss overlaps, gaming, or saturated thickets and have few statistical associations or disassociations of any kind.

This sense is reinforced when in Table 4, where we examine the influence of a paper's contextual attributes on the economic issues that underpin its patent thicket definition. The overall pattern of statistical significance is stronger in Table 4 than it was in Table 3.[50] This suggests that context matters more than theoretical structure when it comes to patent thicket definitions. However, much as before, there is a curious bifurcation: papers about DHCI and overlaps – both significantly associated with being directly about patent thickets – are much more predictable than papers about gaming the patent system and saturated thickets.

It seems that economists favor DHCI and overlaps, cite Shapiro (2001) and do more theoretical work; whereas legal scholars favor overlaps, cite Heller and Eisenberg (1998) and provide discussion. Overlapping patents are curiously related to basic science and the effects of patenting on academic research, both of which depend upon cumulative innovation. Discussing private arrangements and firm strategy, and studying industries with complex products, are rightly associated with DHCI. Gaming the patent system is associated with papers on intellectual property rights reform, which would be reassuring if not for the wildly varying and oft inappropriate reforms (including compulsory licensing) these papers advocate. It also appears that saturating an invention space is frequently advocated as good firm strategy.

[49] The odds ratio of co-occurrence of probabilistic patents cannot be calculated as probabilistic patents are never referred to alone; they are always associated with DHCI (sometimes in conjunction with overlaps or gaming the patent system).

[50] We again report statistical significance using Fisher exact tests, however, we also estimated each specification of Table 4 (columns 3 through 6) using a logit regression. Pseudo-R^2s from logit regressions do not provide accurate measures of variance explained, but they are at least somewhat informative (see Veall and Zimmermann 1996). Across a variety of pseudo-R^2 methods, the typical pseudo-R^2 for each specification was around 20% – closer to 25% for DHCI and overlaps and with percentages in the high teens for gaming and saturated invention spaces.

Table 4: The co-occurrence of economic issues with a paper's contextual attributes

The table documents the co-occurrence of economic issues with various attributes of papers. Column 1 reports the number of papers that an attribute is associated with. In columns 3 through 6 the values are log odds ratios of co-occurrence, with 2-sided Fisher exact tests used to calculate statistical significance. ***, **, and * denote significance at the 0.01, 0.05, and 0.1 levels, respectively. Note that for attributes that are not distinct (i.e., a paper may be both theory and empirical) so the counts do not sum to 164.

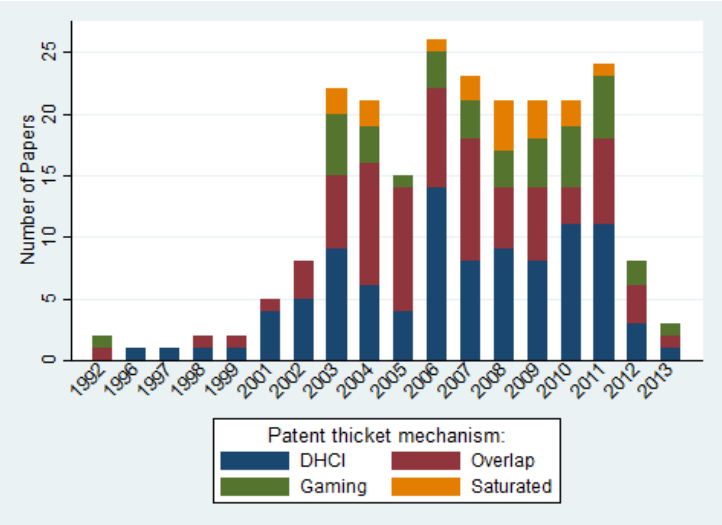
			Log odds ratios of co-occurrence			
	Papers	**Category**	**DHCI**	**Overlap**	**Gaming**	**Saturated**
Pub. Type	70 (43%)	Economics	0.9***	1.2***	0.2	0.4
	13 (8%)	Management	-0.1	0.1	N/A	-0.3
	53 (32%)	Law	-0.5	0.9**	-0.3	-0.5
	11 (7%)	Science	-1.5*	0.3	0.3	N/A
	17 (10%)	Policy report	0.0	0.5	0.7	0.7
Paper Type	57 (35%)	Theory	0.8**	-0.9**	0.1	-0.6
	41 (25%)	Empirical	-0.1	-0.7*	0.2	0.8
	80 (49%)	Discussion	-0.4	0.7**	-0.1	-0.6
Topic	52 (32%)	Patent thickets	0.9**	0.7*	-0.1	-0.5
	12 (7%)	Effects on academics	-0.4	1.9**	N/A	N/A
	78 (48%)	Private arrangements	0.7**	-0.7**	1.2***	1.2**
	24 (15%)	Industry comm.	-2.7***	1.4***	-0.4	-0.3
	81 (49%)	IPR reform	-0.7**	0.4	0.9**	0.1
	50 (30%)	Firm strategy	0.3	1.7***	0.5	1.4**
Industry	57 (35%)	Basic science	-1.2***	1.0***	-0.7	0
	33 (20%)	Complex product	1.5***	-	0	0.6
	11 (7%)	Software/method	-0.6	-0.1	-1.1	N/A

5.4 Time-based variation in issue usage

The results in Tables 3 and 4 neglect temporal considerations. In Figure 1 below we show the number of papers using each patent thicket issue from 1992 to 2013. The drop in 2012 and 2013 is due to delays in the indexing of papers by Google Scholar and journal databases. It almost surely does not reflect any waning research interest in patent thickets.

With the exception of Teece (1988) and Kiley (1992), papers discussing patent thickets were concerned with DHCI and overlapping patents until 2003. In 2003 gaming the patent system and saturated thickets gain more focus in the literature. At this point the proportion of issues used in the literature was 40% : 27% : 23% : 10%, for DHCI, overlaps, gaming, and saturated invention spaces, respectively. After 2003 the change in these proportions is fairly small and they exhibit no clear time trends over the years where we good coverage of definitions.[51] Figure 1 one makes it clear that one economic issue is not displacing the others.

Figure 1: Usage of economic issues over time

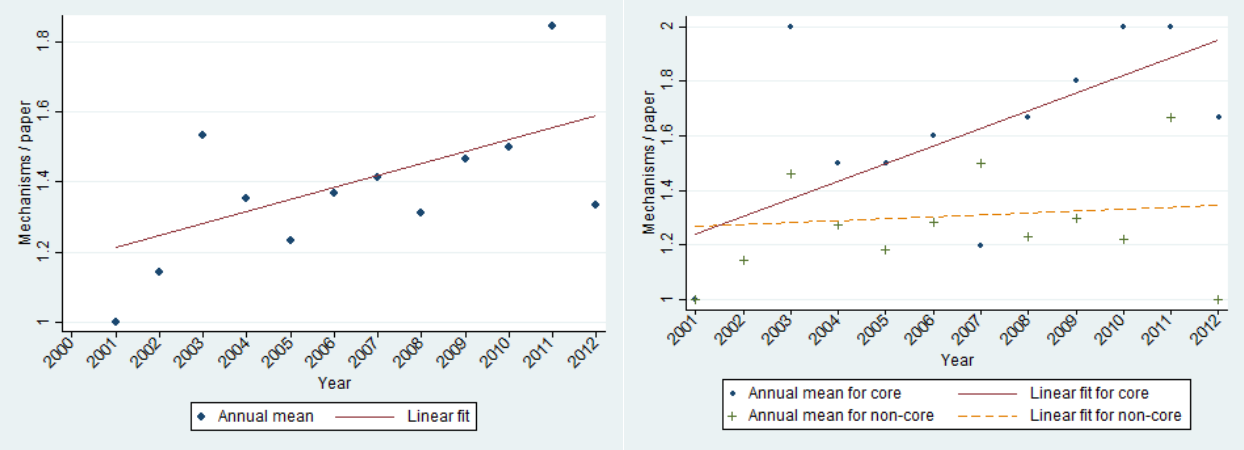


From 2001 to 2012 we have a sufficient number of papers in the sample to make a reasonable estimate of the mean number of issues used per paper each year. In Figure 2a we show that this number has, on average, grown over time. A linear fit suggests statistically significant growth from around 1.2 to around 1.6 patent thicket issues per paper over this period.

[51] Our best estimate of the ratio of occurrence of issues in the future (absent of any influence from this research) is therefore the mean ratio for the 2003 to 2011 period: 41% : 33% : 16% : 9%.

However, Figure 2a masks two separate underlying patterns. Figure 2b show what happens when we divide our sample into a core sub-sample of papers directly about patent thickets and a non-core sub-sample of papers that are largely about other topics. We can now see that the growth in issue usage is almost entirely driven by papers from the core sub-sample.[52]

Figures 2a & 2b: Growth in the number of issues used per paper over time



5.4 Evidence of learning in the core patent thicket literature

Authors of papers about patent thickets are likely to be more informed about the economic issues that underpin patent thicket definitions than authors of papers on other topics. A literature that is becoming more sophisticated might see the propagation of definitions from more informed authors to less informed authors. We therefore look for evidence that non-core papers have similar, but perhaps simplified, definitional compositions to core papers.

In column 1 of Table 5 we show that authors of core papers do use definitions that are consistent with statistically significantly more economic issues than authors of non-core papers. In columns 3 through 5, we show that authors of core papers also use certain modern terms more frequently than authors of non-core papers.[53] This provides evidence that core authors are indeed more sophisticated in their definitions. In column 2, however, we find that authors of core papers are using different definitions than authors of non-core papers.

[52] This could be mechanical as papers that aren't focused on patent thickets typically give much shorter definitions.
[53] Indicator variables for other terms of the art did not achieve statistical significance and so are omitted from the table for brevity.

The results in Table 5 paint an interesting picture that reinforces a finding from Table 4. The evidence suggests that papers directly about patent thickets discuss DHCI and overlapping patents, while non-core papers discuss gaming the patent system and saturated invention spaces. It is not the case that non-core papers have similar, but perhaps simplified, definitional compositions in their definition. Instead they are talking about conceptually different things.

Table 5: What makes papers focused on patent thickets different from those that mention them?

The table shows the results of logit regression specifications where the dependent variable takes the value 1 if the paper is directly about patent thickets and zero otherwise. Heteroskedasticity robust standard errors are provided in parentheses. ***, **, and * denote significance at the 0.01, 0.05, and 0.1 levels, respectively.

		(1)	(2)	(3)	(4)	(5)
	No. issues	0.662***		2.049**		2.684***
		(0.235)		(0.855)		(0.822)
Issue usage indicator variables	DHCI		1.214***	-0.930	0.806*	-1.784**
			(0.425)	(0.862)	(0.484)	(0.897)
	Overlap		1.030***	-1.088	0.986**	-1.686*
			(0.391)	(0.941)	(0.44)	(0.905)
	Gaming		-0.0006	-2.184**	-0.272	-3.189***
			(0.411)	(0.994)	(0.494)	(1.080)
	Saturated		-0.0212	-1.958*	0.258	-2.493**
			(0.608)	(1.101)	(0.672)	(1.040)
Modern terms	Transaction costs			0.651*	0.750	0.772
				(0.377)	(0.469)	(0.495)
	Patent hold-up			0.908**	0.965*	1.125**
				(0.430)	(0.498)	(0.518)
	Constant	-0.733***	-2.035***	-2.430***	-1.456	-1.543
		(0.404)	(0.485)	(0.558)	(0.895)	(0.953)
	Year fixed effects	No	No	No	Yes	Yes
	Observations	164	164	164	150	150
	Pseudo-R^2	0.0420	0.0681	0.120	0.151	0.188

There is an absence of evidence of knowledge flowing from the core patent thicket literature to the adjacent literatures that mention patent thickets. We therefore turn to an examination of learning within the core patent thicket literature. In Table 6 we try to explain the number of economic issues used in a core paper with the year of the paper, the use of modern terms, and two measures of authorship-based sophistication. Having more authors may lead to greater definitional sophistication: authors may each bring their own definitions to a co-authorship, and the resulting paper may then implement a definition consistent with more economic issues. Likewise, repeat authorship may be indicative of increased sophistication: repeat authors may extend their original definitions to support more issues over time.

We find that the year of the paper and the use of modern term from the broader literature on the economics of patents are both associated with the use of a greater number of economic issues in a paper's definition. However, author sophistication measures have no effect on issue use.

Table 6: Explaining the number of issue used in papers directly about patent thickets

The table shows the results of three negative binomial regression estimations. The dependent variable is the number of issues used in a paper, which varies from 0 to 4. The sample is limited to papers directly about patent thickets released from 2001 to 2012. Heteroskedasticity robust standard errors are provided in parentheses. ***, **, and * denote significance at the 0.01, 0.05, and 0.1 levels, respectively.

	(1)	(2)	(3)
Year	0.0461*	0.0383*	0.0407*
	(0.0239)	(0.0223)	(0.0243)
No. of modern terms used		0.230***	0.236***
		(0.0800)	(0.0802)
No. of authors			-0.0110
			(0.0400)
Repeat author?			-0.0406
			(0.189)
Constant	-92.07*	-76.64*	-81.52*
	(47.90)	(44.63)	(48.66)
Observations	47	47	47
Pseudo-R^2	0.0125	0.0336	0.0341

There is a natural relationship between the year of a paper and its use of modern terms, as the broader literature on the economics of patents matured contemporaneously with the patent thicket literature. Nevertheless, the effects of these two measures are largely robust to one another. Table 6 therefore suggests that two separate things are going on. First, patent thicket definitions are becoming slightly more complex each year. This is likely indicative of a growing confusion. And second, papers that use more modern terms are more likely to use more complex definitions. This could be indicative of either a growing confusion or growing sophistication, depending on whether modern terminology use is exogenous or endogenous. That is, authors may consciously choose to include modern terms in order to highlight or reconcile differences between patent thicket issues, or they may be using more complex definitions as they are unable to reconcile the conceptual conflicts that they have with the broader literature.

In Table 7 we examine author consistency to shed some light on which of these cases is more likely. Our measure of author consistency relies on repeat authorship. Authors begin with a consistency score of 1 and then in each subsequent paper have a score on the [0,1] interval that represents the fraction of the issues implemented in the paper relative to their full set of historically used issues. For example, suppose that an author uses DHCI as the foundation of their first patent thicket definition. Their consistency score for this paper is then 1. If the author then goes on to use just overlapping patents in their next paper, their consistency score drops to 0. And if, in their third paper they provides a definition of a patent thicket based on use just DHCI again, their consistency score would rise to ½.[54] Consistency scores for co-authored papers are the average of individual author consistency scores. We use author fixed-effects to examine within author variation.[55]

[54] We do not penalize authors for using a greater number of issues in a subsequent paper, just for inconsistency relative to their full history. Thus if the author in the example used both DHCI and overlapping patent in their second paper but just DHCI in their third paper, their scores would be 1, 1 and 1/2, respectively.

[55] 44 authors have written more than one paper in our sample, of which 10 authors have written 4 or more papers. These ten authors are Von Graevenitz (8 papers), Lerner (7 papers), Hall, Harhoff, and Wagner (6 papers), Layne-Farrar, Tirole, and Van Overwalle (5 papers), and Lemley and Shapiro (4 papers).

Table 7: Author consistency in the choice of patent thicket issues

The table shows the results of three Ordinary Least Squares estimations. The dependent variable is our measure of consistency – the fraction of issues used in a paper's definition relative to the combination of all of the authors' historic issue usage. If the paper is the first time that an author defines a patent thicket, we assign that author a consistency of 1. Author fixed effects are used through-out, so the results convey the consistency of authors who wrote multiple papers. Heteroskedasticity robust standard errors are provided in parentheses. ***, **, and * denote significance at the 0.01, 0.05, and 0.1 levels, respectively

		(1)	(2)	(3)
	Year	-0.0356**	-0.0321*	-0.0272*
		(0.0164)	(0.0155)	(0.0146)
Issue usage indicator variables	DHCI		0.0866	0.118
			(0.150)	(0.141)
	Overlap		0.253*	0.250*
			(0.140)	(0.131)
	Gaming		0.158	0.139
			(0.161)	(0.150)
	Saturated		0.215	0.411
			(0.352)	(0.342)
	Uses modern terminology?			-0.223*
				(0.109)
	Constant	72.35**	65.10**	55.40*
		(32.92)	(31.06)	(29.30
	Author fixed effects	Yes	Yes	Yes
	Observations	164	164	164
	R^2	0.797	0.849	0.876

Our findings are somewhat disturbing. Just three factors have statistically significant effects on author consistency, and none are what we might hope. First, consistency decreases over time. This result is not driven by our choice of a consistency score of 1 as starting value – it result holds if we choose include an indicator variable for first authorship in the patent thicket literature. Second, the use of modern terms is associated with greater inconsistency. This does

not support a story where authors add complexity to their patent thicket definitions as they add more knowledge from adjacent literatures. And third, only the use of overlapping patents is associated with a higher consistency score. Overlapping patents is arguably the most poorly defined patent thicket issue in the literature, and we have already seen in Tables 3 and 4 it has little relation between its theoretical foundations and its practical usage.

6 DISCUSSION AND CONCLUSION

We identify seven difference economic issues that have been referred to as patent thickets. Four of these issues are present in 10% or more of patent thicket definitions in our sample of 164 papers. There is no canonical definition of a patent thicket, and authors frequently implement definitions consistent with more than one issues. This is intentional in a small number of cases but does not appear to be so generally.

We also examine the evolution of the core patent thicket literature (we refer to papers that are direct about patent thickets as core papers). In our sample, the number of economic issues consistent with an average paper's patent thicket definition grew from around 1.2 in 2001 to around 1.6 in 2012. All of this growth comes from an increased complexity in definitions given in core papers.

Authors of core papers use more complex definitions when they use a greater amount of modern terminology from the broader literature on the economics of patents. This could suggest an increasing sophistication in the patent thicker literature. However, authors are also more inconsistent in their issue usage when they use modern terms. Only authors who use overlapping patents are likely to be more consistent in their definition usage. Unfortunately, author inconsistency increases each year even controlling for issue usage in our sample. We therefore suggest that the increasing complexity in patent thicket definitions is a consequence of an increasing confusion in the literature.

One root cause of this confusion is that many definitions of patent thickets have been made by analogy. Many of the original definitions of patent thickets were analogic (see Kiley 1992, Merges 1996, and others). Shapiro (2001)'s colorful analogy is quoted verbatim in more than 50 papers. Even de Russe et al. (2013), who expressly tried to resolve the confusion in patent thicket definitions, were apparently unable to resist explaining that: "A patent thicket conjures up the

image of a bramble, a large dense bush with thorns on the branches making it difficult to pass through without getting severely scratched."

Another cause of confusion is the highly fragmented nature of the patent thicket literature. The peripheral literature is divorced from the core literature. A casual reading also quickly reveals that each branch of the peripheral literature is disconnected from the others. Some papers in the peripheral literature, particularly those engaged in industry commentary and advocating intellectual property rights reform, appear to have improvised their definition of a patent thicket. As the term sounds pejorative, much of this literature is too.

Even with the core patent thicket literature there is fragmentation. Some of this fragmentation is driven by the varied context of papers. Economists predominantly follow Shapiro (2001) and use diversely-held complementary inputs (DHCI), whereas legal scholars predominantly cite Heller and Eisenberg (1998) but use overlapping patents. In a similar vein, empirical work naturally favors a definition of patent thicket that can be measured. Historically, researchers tried to measure DHCI. Their measures were suspect, and are now often used to measure overlapping patents instead.[56] And different industries have different innovation characteristics – life sciences and semiconductors are prone to broad foundational patents, while the ICT sector is prone to problems assembling many adjacent patents. However, context only explains around 20% of the variation in issue usage.

Partly as a consequence of both analogic definitions and the literature's fragmentation, the theoretical foundation of the literature is generally weak. Individual papers do make contributions to theory. Some of these contributions, like that of Heller and Eisenberg (1998), Shapiro (2001), Cockburn and MacGarvie (2011), and others, cemented key foundations of the patent thicket literature. Other contributions, like the notion of overlapping patents (see, for example, Burk and Lemley 2003, and Regibeau and Rockett 2011) have furthered our understanding of patents as imperfectly defined property rights and have had important

[56] Ziedonis (2004) operationalized a Hirchman Herfindahl Index for cited patent ownership that she named the `fragmentation index'. It was supposed to capture the extent to which complementary inputs are diversely-held but it is unclear how or why patent citations would convey this information. Von Graevenitz (2011) introduced a related measure of patent thickets for researchers using European data. This measure is based on `X' and `Y' citations, which are added by search examiners to indicate potential conflicts with prior art. These conflicts should be resolved before the patent is issued, making the semantics of Von Graevenitz (2011)'s measure debatable.

ramifications for the broader literature. But there is little sense of theoretical coherence in the patent thicket literature.

The confusing state of affairs that we document indicates the failure of some scholars to meeting some of the most basic criteria of good scholarly inquiry: precise definitions, clear assumptions, careful study of the phenomenon, and engagement with and understanding of research authored in related disciplines or professions. This would perhaps be of little consequence if patent thickets were a purely academic concern. Unfortunately, implementers, and some follow-on innovators, treat pre-existing patents as costs and want licensing to be cheap or even free and compulsory, whereas foundational innovators, and possibly some people who may be gaming the patent system, want the rents from patents to be sacrosanct. The rhetoric of patent thickets is therefore 'partisan' with both sides engaging in non-market strategy – each trying to affect policy and outcomes in the courts. The current fever-pitch battle has the future of the innovation economy at stake, which should demand careful scholarship.

Worse still, we find that the papers that are most accessible to practitioners and policy-makers use quite different definitions of a patent thicket from those discussed by academic experts, yet they use the same term. A divergent array of definitions allows an abundance of conflicting findings. Opportunistic policy-advocates can then pick and choose the facts to suits their purposes. This is not a recipe for successful policy analysis, let alone welfare enhancing policy action.

It would be nice to conclude this paper by answering the two big questions in the literature: Do patent thickets exist? And do patent thickets cause economic inefficiencies? But, despite carefully reading and analyzing the 164 papers that make up our sample, what we can say is limited.[57] Theoretically, all seven patent thicket issues could exist, and five of these issues could cause economic inefficiencies. Three of these five (DHCI, overlaps, and transaction costs) could have their theoretical efficiency loss addressed by private arrangements, of which there are many different kinds already in place in practice. Another of these five, saturated invention spaces, concerns patenting adjacent innovations and so is a natural response to competition given imperfect appropriability (see Teece, 1998). Only if people are systematically gaming the patent

[57] Our sample includes the near-population of 23 papers (including survey and measures papers) that have carried out empirical research into patent thickets

system would there necessarily be dire welfare consequences. But there is simply no evidence that this is the happening even in areas like software.[58]

> *"The idea of a 'thicket' or 'anti-commons' in the software industry is difficult to credit. When raised in my interviews, that thesis universally was rejected… the patent system is not systematically preventing the initiation of product development. Beyond that, it is plain that the system is not obviously dysfunctional."* -- Mann (2004)

We are currently experiencing the greatest innovation economy in human history. Of course, it could always be greater. Industries with complex products that may be particularly prone to patent thicket problems don't appear to be lagging other industries. Instead they appear to be leading them in important measures like decline in real prices (see, for example, Haber 2014). Complex products dominant Scientific American's lists of greatest inventions, and at least four of its top ten inventions (automobiles, airplanes, wireless telegraphy, and electrical generators) were associated with 'patent thicket' rhetoric in their early years. This time around the focus is on smartphones, semiconductors, nanotechnology and genetics. In the words of Mark Twain: history doesn't repeat itself, but it does rhyme.

The greatest threat to the innovation ecosystem is then ill-advised reform. The Federal Trade Commission has lead the way in this regard. We therefore conclude with a quote from Shapiro (2001) who suggests that their efforts are misplaced.[59]

> *"So far, the Department of Justice has displayed a keen understanding of the need for those holding complementary rights to coordinate in the licensing of those rights, but the Federal Trade Commission has exhibited less restraint, and arguably is making it more difficult for firms [to resolve patent thicket problems]"* -- Shapiro (2001)

[58] Software and business methods are two of the most contentious patenting areas.
[59] Teece and Sherry (2003), Epstein et al. (2012), and others, provide similar statements.

7 APPENDIX

Table A1: Economic issues, modern term use, and other data for core papers

Paper	Pub. type	Saturated	DHCI	Overlapping	Gaming	Probabilistic	Search cost	Transaction cost	(Patent) Hold-up	Strategic patents	Hold-out	Theory	Empirical	Discussion	Basic Science	Complex Product	Software / Bus. Mthd	Effects on academia	Private Mechanisms	Industry Commentary	IPR Reform	Firm Strategy
Bessen (2003)	Econ	·	✓	✓	✓	✓	·	✓	✓	·	·	✓	·	·	·	✓	·	·	✓	·	·	✓
Clarkson (2004)	Econ	✓	✓	✓	·	·	·	✓	✓	·	·	·	✓	·	·	✓	·	·	·	·	·	·
Clarkson (2005)	Econ	·	·	✓	·	·	·	·	·	·	·	·	✓	·	·	✓	·	·	·	·	·	·
Clarkson & DeKorte (2006)	Mgmt	·	✓	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	·	·	·
Cockburn & MacGarvie (2009)	Econ	·	✓	✓	✓	·	·	✓	·	·	✓	·	✓	·	·	·	✓	·	·	·	·	✓
Cockburn & Macgarvie (2011)	Mgmt	·	·	·	·	·	·	✓	·	·	·	·	✓	·	·	·	✓	·	·	·	·	✓
Cockburn et al. (2010)	Econ	✓	✓	✓	·	·	·	✓	·	·	✓	·	✓	·	·	✓	·	·	·	·	·	✓
de Russe et al. (2014)	Policy Rpt.	✓	✓	✓	✓	·	·	·	·	·	✓	·	·	✓	·	·	·	·	·	·	✓	·
Entezarkheir (2010)	Mgmt	·	✓	·	·	·	·	✓	✓	·	·	·	✓	·	·	✓	·	·	·	·	·	✓
EPO (2012)	Policy Rpt.	·	✓	✓	✓	·	·	✓	·	✓	·	·	·	✓	·	·	·	·	·	·	✓	·
Epstein & Kuhlik (2004)	Law	·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	·	·	·
Evans & Layne-Farrar (2004)	Mgmt	·	·	✓	·	·	·	✓	·	✓	·	·	·	✓	·	·	✓	·	·	·	✓	·
Farrell (2009)	Econ	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·	·	·	·	✓	·	·	·
Galasso (2007)	Econ	·	✓	·	·	·	·	·	✓	·	·	✓	✓	·	·	✓	·	·	✓	·	·	✓
Galasso & Schankerman (2010)	Econ	·	✓	·	·	·	·	✓	·	·	·	·	✓	·	·	·	·	·	·	·	·	·
George (2006)	Law	·	✓	·	·	·	·	✓	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·
Geradin (2007)	Econ	·	✓	·	·	·	·	✓	✓	·	·	·	✓	·	·	·	·	·	·	·	·	·
Geradin et al. (2008)	Econ	·	✓	·	·	·	·	✓	·	·	·	·	·	✓	✓	✓	✓	·	·	·	·	·
Hall (2012)	Policy Rpt.	·	·	✓	·	·	·	✓	·	·	·	·	✓	·	·	·	·	·	·	·	·	·
Hall & Ziedonis (2001)	Econ	·	✓	·	·	·	·	·	·	✓	·	✓	✓	·	·	✓	·	·	·	·	·	·
Hall & Ziedonis (2007)	Econ	·	✓	·	·	·	·	·	✓	·	·	·	✓	✓	·	✓	·	·	·	·	·	✓
Hargreaves (2011)	Policy Rpt.	·	✓	✓	✓	·	·	·	·	·	✓	·	·	✓	·	·	·	·	·	·	✓	·
Harhoff (2007)	Policy Rpt.	·	✓	·	·	·	·	✓	·	✓	·	✓	·	✓	·	·	·	·	·	·	✓	✓
Harhoff (2008)	Econ	·	✓	✓	✓	·	·	✓	·	✓	·	·	✓	·	·	·	·	·	·	·	·	·
Harhoff et al. (2012)	Econ	·	·	✓	·	·	·	·	✓	·	·	·	✓	·	·	·	·	·	·	·	·	·
Hegde et al. (2009)	Econ	·	·	·	✓	·	·	·	·	✓	·	·	✓	·	·	·	·	·	·	·	·	✓
Heller (1998)	Law	·	✓	·	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	·	·	·	·
Heller & Eisenberg (1998)	Law	·	✓	✓	·	·	·	✓	·	✓	·	✓	·	·	✓	·	·	·	·	·	·	·
Huang & Murray (2009)	Mgmt	·	✓	✓	·	·	·	✓	·	·	·	·	✓	·	✓	·	·	✓	·	·	·	·
Kiley (1992)	Law	·	·	✓	✓	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	·	·	·
Lessig (2001)	Law	·	·	✓	·	·	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·
Lin (2011)	Econ	·	✓	·	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·	·	✓
Mann (2004)	Law	·	·	✓	·	·	·	·	·	·	·	·	✓	·	·	·	✓	·	✓	·	✓	·
Mann (2005)	Law	·	·	✓	·	·	·	✓	·	·	·	✓	✓	·	·	·	✓	·	·	·	·	✓
Merges (1996)	Law	·	✓	·	·	·	·	·	·	·	·	✓	·	✓	·	·	·	·	·	·	·	·
Merges (1999)	Law	·	✓	✓	·	·	·	✓	✓	·	·	·	·	✓	·	·	·	·	·	·	✓	·
Mossoff (2009)	Econ	·	✓	✓	·	·	·	✓	·	·	✓	·	·	✓	·	✓	·	·	✓	·	·	·
Mossoff (2011)	Econ	·	✓	✓	·	·	·	✓	·	·	✓	·	·	✓	·	✓	·	·	✓	·	·	·
Murray & Stern (2007)	Econ	·	·	✓	·	·	·	·	·	·	·	·	✓	✓	✓	·	·	✓	·	·	·	·
Nagaoka & Nishimura (2006)	Mgmt	·	✓	✓	·	·	·	·	✓	·	·	·	✓	·	·	·	·	·	·	·	·	·
Noel & Schankerman (2006)	Econ	·	✓	·	·	·	·	✓	·	✓	·	·	✓	·	·	·	✓	·	✓	·	·	✓
Regibeau & Rockett (2011)	Policy Rpt.	·	✓	✓	·	✓	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·
Reitzig (2004)	Econ	·	✓	·	·	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	·	·	·
Shapiro (2001)	Econ	·	✓	·	·	·	·	·	·	·	·	✓	·	✓	·	·	·	·	✓	·	·	·
Siebert & von Graevenitz (2010)	Econ	·	✓	✓	✓	✓	·	·	✓	✓	·	✓	✓	·	·	✓	·	·	·	·	·	✓
Siebert & von Graevenitz (2010)	Econ	·	✓	·	✓	·	·	·	✓	✓	·	✓	✓	·	·	✓	·	·	·	·	·	✓
Sternitzke et al. (2008)	Econ	✓	·	·	·	·	·	·	·	·	·	·	✓	·	·	✓	·	·	·	·	·	·
Strandburg (2006)	Law	·	✓	✓	·	·	·	✓	·	·	·	·	✓	✓	·	·	·	·	·	·	·	·
von Graevenitz (2012)	Econ	·	✓	✓	✓	·	·	·	✓	·	·	·	✓	·	·	·	·	·	·	·	·	·
von Graevenitz et al. (2011)	Econ	·	✓	✓	·	·	·	·	✓	·	·	·	✓	·	·	·	·	·	·	·	·	·
Walsh et al. (2003)	Law	·	✓	·	·	·	·	·	✓	·	·	·	·	✓	✓	·	·	✓	·	·	·	·
Ziedonis (2004)	Econ	·	✓	·	·	✓	✓	✓	·	·	·	·	✓	·	·	✓	·	·	✓	·	·	·

Table A2: Economic issues, modern term use, and other data for non-core paper

Paper		Publication Type	Saturated	DHCI	Overlapping	Gaming	Probabilistic	Search cost	Transaction cost	(Patent) Hold-up	Strategic patents	Hold-out	Theory	Empirical	Discussion	Basic Science	Complex Product	Software / Bus. Mthd	Effects on academia	Private Mechanisms	Industry Commentary	IPR Reform	Firm Strategy
Aggarwal & Hsu (2009)	Econ		✓	·	·	·	·	·	·	·	·	·	·	✓	·	✓	·	·	·	·	·	·	✓
Allison & Tiller (2003)	Law		·	·	✓	·	·	·	·	✓	·	·	·	✓	·	·	·	✓	·	·	·	✓	·
Andrews (2002)	Polict Rpt.		·	✓	·	·	·	·	·	·	·	·	·	·	✓	✓	·	·	✓	✓	·	✓	·
Aoki & Schiff (2008)	Econ		·	✓	✓	·	·	·	✓	·	·	·	✓	·	·	·	·	·	·	✓	·	·	·
Arundel & Patel (2003)	Polict Rpt.		·	✓	✓	·	·	·	✓	·	✓	·	·	·	✓	✓	·	·	✓	·	·	✓	·
Attaran (2004)	Polict Rpt.		·	·	✓	✓	·	·	✓	·	·	·	·	·	✓	✓	·	·	·	·	✓	✓	·
Ayres & Parchomovsky (2007)	Law		·	✓	✓	✓	·	✓	✓	✓	·	·	✓	·	·	·	·	·	·	✓	·	✓	·
Baluch et al. (2005)	Law		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	✓	·	·	·
Baron & Delcamp (2010)	Econ		·	✓	·	·	·	·	✓	·	·	·	·	✓	·	·	✓	·	·	✓	·	·	✓
Baron & Pohlmann (2011)	Econ		·	✓	·	✓	·	·	✓	·	·	·	✓	✓	·	·	✓	·	·	✓	·	·	✓
Barpujari (2010)	Mgmt		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	✓	·	✓	·
Barton (2002)	Law		·	✓	·	·	·	·	·	·	✓	✓	✓	·	·	·	✓	·	·	✓	·	✓	✓
Baumol (2004)	Econ		·	✓	·	·	·	·	·	·	·	·	·	·	✓	·	✓	·	·	✓	·	·	✓
Bawa (2005)	Gen Sci.		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	✓	✓	·	·
Bawa (2007)	Law		·	·	✓	✓	·	·	·	·	·	·	·	·	✓	✓	·	·	·	✓	✓	✓	·
Bawa et al. (2005)	Law		·	·	✓	·	·	·	·	·	·	·	✓	·	·	✓	·	·	·	·	✓	✓	✓
Beard & Kaserman (2002)	Law		·	✓	✓	·	·	·	·	·	·	✓	✓	·	·	·	✓	·	·	✓	·	✓	·
Bergman & Graff (2007)	Gen Sci.		·	·	✓	·	·	·	✓	·	·	·	·	·	✓	✓	·	·	·	✓	✓	·	·
Braun & Herstatt (2007)	Econ		·	✓	✓	·	·	·	·	·	·	·	✓	·	·	✓	·	·	·	✓	·	·	✓
Burk & Lemley (2003)	Law		·	·	✓	✓	·	·	·	·	·	·	✓	·	·	·	·	·	·	·	✓	✓	·
Calderini & Giannaccari (2006)	Econ		·	✓	✓	·	·	·	✓	·	·	·	·	·	✓	·	✓	·	·	✓	·	✓	·
Callaway (2008)	Law		·	✓	·	·	·	✓	·	·	·	·	✓	·	·	·	✓	·	·	·	·	✓	✓
Carrier (2002)	Law		·	·	✓	·	·	·	·	·	·	·	·	·	✓	·	·	·	·	✓	·	✓	·
Carrier (2003)	Law		·	✓	·	·	·	·	·	·	·	✓	✓	·	·	·	·	·	·	✓	·	✓	·
Carrier (2004)	Law		·	·	✓	·	·	·	·	✓	·	·	✓	·	·	·	·	·	·	✓	·	✓	·
Choi (2005)	Econ		·	·	·	✓	·	·	·	·	·	·	✓	·	·	·	·	·	·	·	·	✓	·
Cohen & Walsh (2008)	Econ		·	·	✓	·	·	·	✓	·	·	·	·	✓	·	✓	·	·	✓	✓	·	✓	·
Competition (2008)	Polict Rpt.		✓	·	·	·	·	·	·	·	·	·	·	✓	·	✓	·	·	·	·	✓	✓	·
Cowin (2007)	Polict Rpt.		✓	·	✓	·	·	·	·	·	✓	·	·	·	✓	·	·	·	·	✓	·	✓	·
Devlin (2009)	Law		·	✓	·	·	·	✓	·	✓	·	✓	✓	·	·	·	·	·	·	✓	·	✓	·
Dhar & Foltz (2007)	Econ		·	·	✓	·	·	·	·	·	·	·	✓	✓	·	✓	·	·	·	·	✓	✓	✓
D'Silva (2009)	Law		·	✓	✓	·	·	·	✓	·	·	·	·	·	✓	✓	·	·	·	✓	✓	✓	·
Eisenmann (2008)	Mgmt		·	✓	·	·	·	·	·	·	·	·	·	·	✓	·	✓	·	·	✓	·	·	✓
Eisenstein (2010)	Gen Sci.		·	·	·	✓	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	✓	·	✓
Feldman (2004)	Law		·	·	✓	·	·	·	✓	·	·	·	✓	·	✓	✓	·	·	✓	✓	·	·	·
Feldman & Nelson (2008)	Law		·	·	✓	·	·	·	✓	·	·	·	✓	·	·	✓	·	·	·	✓	·	·	·
FTC (2003)	Polict Rpt.		·	·	✓	✓	·	·	·	·	·	·	·	·	✓	✓	✓	·	·	·	·	✓	·
FTC (2011)	Polict Rpt.		·	✓	✓	✓	·	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·
Gallini (2011)	Econ		·	✓	✓	·	·	·	·	·	·	·	✓	·	·	·	·	·	·	✓	·	·	·
Ganslandt (2009)	Econ		·	✓	·	·	·	·	✓	·	·	·	·	·	✓	✓	✓	·	·	✓	·	✓	·
Gaule (2006)	Mgmt		·	✓	·	·	·	·	✓	·	·	·	·	·	✓	✓	·	·	·	✓	✓	·	·
Gilbert (2010)	Law		·	✓	·	·	·	✓	✓	·	·	·	·	·	✓	·	·	·	·	✓	·	✓	·
Glover (2002)	Law		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	·	✓	·
Goozner (2006)	Gen Sci.		·	·	✓	·	·	·	✓	·	·	✓	·	·	✓	✓	·	·	·	✓	✓	✓	·
Hall (2007)	Econ		·	✓	·	·	·	·	·	✓	✓	·	✓	·	✓	✓	✓	·	·	·	·	✓	✓
Hemphill (2003)	Econ		✓	·	·	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	✓	✓	✓
Holman (2005)	Law		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	✓	✓	·
Holman (2006)	Law		·	·	✓	·	·	·	✓	·	·	✓	·	·	✓	✓	·	·	✓	·	✓	✓	·
Holman (2008)	Gen Sci.		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	✓	·	·
Horn (2003)	Law		·	✓	·	·	·	·	·	·	·	·	·	·	✓	✓	✓	·	·	✓	·	·	·
Hussinger (2006)	Econ		✓	·	·	✓	·	·	·	·	✓	·	·	✓	·	·	✓	·	·	·	·	·	✓
Iyama (2005)	Law		·	·	✓	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	✓	·	✓	·
Jacob (2009)	Polict Rpt.		·	·	·	·	·	·	·	·	·	·	·	·	✓	✓	·	·	·	·	✓	✓	·
Jensen & Webster (2004)	Econ		·	·	·	✓	·	·	·	·	·	·	✓	·	·	·	·	·	·	·	·	✓	·

Paper		Publication Type	Saturated	DHCI	Overlapping	Gaming	Probabilistic	Search cost	Transaction cost	(Patent) Hold-up	Strategic patents	Hold-out	Theory	Empirical	Discussion	Basic Science	Complex Product	Software / Bus. Mthd	Effects on academia	Private Mechanisms	Industry Commentary	IPR Reform	Firm Strategy
Kato (2004)	Econ				✓								✓							✓			
Kesselheim & Avorn (2005)	Gen Sci.				✓										✓	✓			✓	✓	✓	✓	
Kim (2004)	Econ			✓					✓				✓							✓			✓
King (2007)	Law				✓	✓				✓					✓							✓	
Kwon (2012)	Econ			✓						✓	✓		✓				✓			✓			✓
Lampe & Moser (2012)	Econ					✓					✓			✓						✓			✓
Lanjouw & Schankerman (2004)	Econ			✓					✓					✓						✓			✓
LayneFarrar (2007)	Econ		✓										✓							✓		✓	
LayneFarrar & Lerner (2011)	Econ			✓										✓						✓			✓
Leaffer (2009)	Law		✓			✓							✓							✓		✓	✓
Lee (2006)	Law				✓					✓					✓	✓				✓	✓			
Lei et al. (2009)	Gen Sci.				✓									✓		✓			✓			✓	
Lemley (2005)	Law			✓	✓										✓	✓			✓	✓		✓	
Lemley & Shapiro (2005)	Econ			✓									✓			✓				✓		✓	
Lemley & Shapiro (2006)	Econ			✓									✓				✓			✓		✓	
Lerner et al. (2003)	Econ			✓										✓						✓			✓
Lerner & Tirole (2002)	Econ			✓									✓							✓			
Lerner & Tirole (2005)	Econ			✓									✓							✓			
Lerner & Tirole (2008)	Econ			✓					✓	✓		✓	✓							✓		✓	
Lerner et al. (2007)	Econ				✓								✓	✓						✓			
Lerner & Zhu (2007)	Econ			✓										✓				✓				✓	
Lin (2001)	Law			✓								✓	✓					✓		✓			✓
Liu (2008)	Econ		✓											✓		✓							✓
Llanes & Trento (2009)	Econ			✓					✓	✓			✓							✓		✓	
Macdonald (2004)	Mgmt				✓				✓						✓							✓	✓
Mallo (2008)	Gen Sci.					✓									✓	✓						✓	✓
Maskus (2006)	Econ			✓		✓			✓						✓							✓	
Masur (2010)	Law		✓			✓		✓							✓							✓	
Meniere (2008)	Econ			✓		✓							✓			✓	✓					✓	
Merges (2006)	Law			✓						✓					✓					✓		✓	
Mertes & Stotter (2010)	Gen Sci.			✓								✓			✓	✓				✓			✓
Meurer (2002)	Law			✓											✓					✓		✓	✓
Muris (2001)	Polict Rpt.			✓						✓					✓					✓		✓	
Napoleon (2009)	Law		✓	✓	✓										✓	✓						✓	✓
Nielsen & Samardzija (2006)	Law			✓					✓						✓					✓		✓	
Palangkaraya et al. (2011)	Econ				✓						✓			✓								✓	✓
Paredes (2006)	Law			✓	✓	✓									✓	✓						✓	
Rai (2003)	Law				✓				✓	✓	✓		✓		✓							✓	
Rey & Salant (2012)	Econ			✓									✓							✓		✓	
Rubinfeld & Maness (2004)	Law		✓			✓					✓				✓							✓	✓
Sabety (2004)	Law				✓			✓	✓						✓	✓				✓	✓	✓	
Santore et al. (2010)	Econ			✓						✓			✓	✓						✓			
Schacht (2006)	Polict Rpt.										✓	✓			✓	✓		✓			✓	✓	
Schmalensee (2009)	Econ					✓							✓							✓		✓	
Schmidt (2008)	Econ			✓									✓							✓			✓
Schneider (2008)	Econ		✓	✓									✓										✓
Shand & Wetter (2007)	Law				✓										✓	✓					✓	✓	
Shapiro (2003)	Econ			✓		✓							✓							✓		✓	✓
Somaya (2003)	Mgmt		✓							✓	✓		✓	✓		✓	✓			✓			✓
Somaya et al. (2011)	Mgmt			✓					✓				✓										✓
Taylor & Cayford (2003)	Law			✓	✓								✓			✓					✓	✓	
Tullis (2005)	Law			✓	✓										✓	✓			✓			✓	
VanOverwalle (2010)	Gen Sci.			✓		✓									✓	✓				✓		✓	
VanZimmeren (2006)	Polict Rpt.			✓					✓						✓	✓				✓			
Verbeure (2006)	Gen Sci.			✓					✓						✓	✓				✓			
Wagner (2003)	Law			✓									✓		✓		✓					✓	
Wang (2010)	Law			✓				✓	✓						✓		✓			✓			

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