NBER WORKING PAPER SERIES

THE CHOICE BETWEEN FORMAL AND INFORMAL INTELLECTUAL PROPERTY: A LITERATURE REVIEW

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Working Paper 17983
http://www.nber.org/papers/w17983

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2012

The source of funding for this paper was the United Kingdom Intellectual Property Office. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

At least one co-author has disclosed a financial relationship of potential relevance for this research. Further information is available online at http://www.nber.org/papers/w17983.ack

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NBER Working Paper No. 17983
April 2012
JEL No. K11,L29,O34

ABSTRACT

We survey the economic literature, both theoretical and empirical, on the choice of intellectual property protection by firms. Our focus is on the tradeoffs between using patents and disclosing versus the use of secrecy, although we also look briefly at the use of other means of formal intellectual property protection.

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Judges and lawyers have sometimes thought that because trade secret law provides less protection to the inventor than patent law does, no rational person with a patentable invention would fail to seek a patent. […] This reasoning is incorrect.

Friedman et al. (1991: 62-63)

1. Introduction

US$500,000 per patent: this figure circulated widely following Google's announcement of its takeover of Motorola (*Economist* 17 August 2011). This value is obtained by dividing the price paid by Google for the acquisition of Motorola (US$12.5 billion) by the number of patents held by Motorola (24,000). Applying a similar logic, the acquisition of the patents assigned to Canadian Nortel by a consortium of firms in July 2011 yields an even higher price tag of US$750,000 per patent.[1] Comparing the trading value of commercial secrets is more difficult, since the trading of secrets is by definition much harder to observe empirically, but some figures can still be obtained from court rulings. For example, in a recent ruling by a federal court in Virginia in September 2011, Kolon Industries Inc. was held liable to paying DuPont Co. the amount of US$919.9 million for the theft of 149 trade secrets related to the production of Kevlar, a special fiber (Bloomberg 15 September 2011). This suggests an average value of US$6.3 million per trade secret. These computations are certainly naïve, but the figures nevertheless indicate that firms use both patents and trade secrets to protect valuable inventions and contrary to a commonly encountered belief, patents may not necessarily protect a company's most valuable inventions.

What determines a company's decision to opt for patents or secrecy, or put more broadly, to choose between formal intellectual property (IP) and "alternative" or informal appropriation mechanisms? This paper reviews the theoretical and empirical literature concerning the choice between formal IP, in the form of registered and unregistered IP, and "alternative" or informal appropriation mechanisms in providing incentives for invention and innovation, as well as in shaping a firm's ability to commercially exploit its knowledge. The goal is to discuss the current state of knowledge about the determinants of a firm's decision to use formal or informal IP to protect and exploit innovation.

Formal IP is designed to provide *ex ante* incentives to innovate by providing a reward system that makes it easier for innovators to make *ex post* profits if their innovation is successful, by allowing them to exclude imitators for a finite period. This means that innovation can potentially be performed by any agent in the economy and that innovators themselves are left to judge whether their innovations are worth further investment and how to exploit them commercially.

[1] The consortium comprised Microsoft, Apple, Ericsson, EMC, Sony, and Research in Motion.

The financial reward to an IP holder derives from the legal right to exclude others from using the innovation and addresses the fundamental problem of *appropriability* that governs the production of knowledge. As Geroski (1995, p. 91) states, "[t]he feature of inventive and innovative activity that most clearly sets it apart from other strategic investments made by firms is the problem of appropriability." Appropriability is a concern for inventors since one of the outputs of inventive and innovation activity is often knowledge, an intangible asset, hence it is difficult to exclude others from using this knowledge at a fraction of the initial cost of the invention development.[2] Although there may be important additional reasons for setting up an IP system, the appropriability problem is usually considered to be the basic economic justification for an IP system because such a system allows the inventor/innovator to appropriate most of the returns from the initial innovation investment by excluding third parties from using the innovation. Nevertheless, invention and innovation do occur even if firms cannot access, or choose not to use, the IP system. As will be reviewed below, firms have a range of strategies – such as secrecy or first mover advantage – by which they will try to appropriate any rewards to invention and innovation and the available empirical evidence suggests that firms rely on these alternative mechanisms much more than on registered IP.[3]

Thus from an inventor's point of view, the IP system allows him or her to derive at least some return from investing in innovation. From a social point of view, granting a temporary property right on an innovation, for example in the form of a patent, is justified on the basis that the inventor is, in exchange, required to explain the innovation in a specific, standardized technical format (that can be read and understood by qualified third parties). The economic justification for this disclosure is to allow other firms to avoid duplication of research, possibly acquire useful knowledge and, when the patent expires, quickly imitate the innovation. These issues are stressed by endogenous growth theories, which demonstrate the importance of knowledge spillovers among firms and sectors for sustained long-run growth (Romer, 1990). In this respect, the disclosure of knowledge required by a patent application in principle allows knowledge to reach other firms and individual inventors and may help avoid wasteful duplication of research efforts; secrecy, on the contrary, may hinder the circulation of new ideas and therefore slow down knowledge spillovers and economic growth.[4]

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[2] In some cases, the fraction may be fairly large, in that successful imitation is costly even when the imitator has acquired the relevant knowledge (Mansfield *et al.*, 1981).

[3] In basic terms one can think of invention being only the first step in a complex process with the end point being a successful innovation. Formally, a patent describes the invention, and not the innovation that may come later. In this paper we do not generally refer to this distinction unless it is critical.

[4] However, there is a debate about to what extent firms use patent documents to obtain information. Lemley (2008) is one of many with experience as practitioners to suggest that IT and biotech firms in the U. S. purposefully ignore existing patent documents in order to avoid charges of willful infringement and that researchers in these fields execute their research without conducting "prior art" searches. Supportive of this view, Cockburn and Henderson (2003) provide survey evidence collected among company IP

The availability and use of the different appropriability regimes differ across technologies and sectors; some of the differences are due to differences in legal systems and exogenous characteristics of the technologies employed. Endogenous industry demographics and market structure also account for some of the observable heterogeneity across industries in firms' choices between formal and informal IP. However, the appropriability regime also depends on firms' strategic competitive behavior.

The main forms of formal IP are patents, trademarks, designs and copyright.[5] The first three of these are registered rights, while copyright is an unregistered right.[6] In addition, trade secrecy can also be regarded as a part of IP, although in most common law countries, including the UK and the US, trade secret law forms part of common law and therefore its protection is weaker than in other countries.[7] In the US, trade secrecy also has been enforced at the state level historically. As discussed later in the paper, following the Uniform Trade Secrets Acts of 1979 and 1985, many states have standardized the code relating to trade secrecy. Since the underlying mechanisms differ for registered and unregistered IP, we distinguish in this review between registered IP, paying particular attention to patents as they protect technologies, and unregistered IP in the form of copyright as well as most informal mechanisms. Informal IP may take various forms; commonly secrecy, confidentiality agreements, lead time, and complexity (of design) are subsumed under the informal IP heading.[8] Similar to unregistered formal IP, informal IP remains, by construction, largely unobserved to third parties, which creates a formidable challenge for empirical work as will be discussed in detail below.

The fundamental question that we address in this review is the following: is there any reason why a firm with a given innovation that can be protected by formal IP would choose *not* to rely on such IP to protect an innovation? In search of explanations for this type of firm behavior, we review the theoretical literature and assess the empirical evidence to determine which of the theoretical arguments are supported by the

managers, which we will discuss in more detail further below, that shows that only a third of respondents conduct a prior art search before starting new R&D or product development. In a recent paper, Ouellette (2011) provides contrasting evidence that suggests that managers of nanotechnology firms find it useful to read patent documents.

[5] Other registered IP includes plant breeders' rights and semiconductor topography rights. Other unregistered IP includes unregistered designs, trademarks, and company symbols.

[6] Much more detail on the nature and history of these rights can be found in Greenhalgh and Rogers (2010).

[7] Since enforcement through common law is difficult in practice, trade secrets are often enforced through specific contracts, such as confidentiality or non-disclosure agreements. Although these documents are not a legal requirement for the enforcement of trade secrets in court, Almeling et al. (2010) present evidence that the secret owner is more likely to prevail against employees or business partners if such an agreement exists.

[8] The "informal" label does not imply the absence of legal contracts and obligations.

available data. As we will discuss below, the existing evidence shows that there are enormous differences in the use of IP at the firm-level – differences that are beyond expected differences in the applicability of IP to (especially patentability) firms' innovations.[9] The evidence available from various firm-level surveys, which is reviewed below, suggests that on average, firms rely more on informal than formal IP to protect their inventions, and that most firms use no IP protection at all.

Table 1 uses data collated from the UK Community Innovation Surveys to illustrate this point.[10] The table shows the % share (using sampling weights to produce population estimates) of companies indicating (a) no use, (b) low use, (c) medium, or (d) high use of formal, registered, and informal IP. It shows that only 22 per cent of firms use any formal IP protections, whereas one third use some form of informal IP. The least used IP protection is patenting, with only 16 percent of the firms making any use of this method.

Table 1: Use of different IP mechanisms by UK (%)

IP mechanism	Not used	Low	Medium	High
Formal IP	78.0	11.4	6.9	3.7
Registered IP	80.7	9.8	6.0	3.5
Patents	83.8	5.9	4.4	5.9
Informal IP	66.2	14.9	13.1	5.8
Secrecy	67.8	11.2	11.5	9.5

Note: Formal IP contains patents, trademarks, registered designs, and copyright; Registered IP contains patents, trademarks, and registered designs; Informal IP contains secrecy, lead time, complexity, confidentiality.
Data source: UK ONS CIS 3, 4, and 5; Table contains population-weighted shares based on 38,760 observations.

Of course, one reason for not using IP protection is that there is nothing that needs protecting. In Table 2 we look at the firm's importance rating of IP stratified by the type of innovation the firm has undertaken. Only about 30 per cent of the firms have introduced a new product or process during a three-year period. These firms are indeed more likely to use some form of IP protection, especially if they are product innovators. However, even among the most innovative, with both product and process innovation, about half of the firms rate formal IP as of no importance and 20 per cent do not even consider informal IP of any importance. In general, the use of IP increases as the type of innovation goes from process only to product only to both product and process and as the IP goes from formal to informal.

[9] See for example Rogers *et al.* (2007).

[10] These data come from the UK CIS 3, 4, and 5, covering the years 1998-2007.

Table 2: Importance of different IP mechanisms by type of innovative firm (%)

	Innovating type	Not used	Low	Medium	High
Formal IP	Non-innovator	88.9	6.7	2.8	1.7
	Process only	72.8	15.1	8.6	3.2
	Product only	55.9	20.5	16.0	7.7
	Both product & process	45.5	25.3	18.9	10.4
Registered IP	Non-innovator	90.2	5.8	2.4	1.6
	Process only	77.7	11.4	7.6	3.2
	Product only	60.5	18.4	13.9	7.2
	Both product & process	52.3	21.7	16.1	9.9
Informal IP	Non-innovator	82.6	10.7	5.7	1.6
	Process only	47.7	25.2	19.8	7.3
	Product only	35.3	24.7	27.5	12.5
	Both product & process	20.8	22.7	35.8	20.7

See notes to Table 1.

Table 3, drawn from the US National Science Foundation's new BRDIS survey, shows similar results for US firms. Looking at all firms in all industries, only a small fraction find any form of IP important to them, and the rank of importance in terms of the share of firms is trademark, trade secret, copyright, design patent, and utility patent. When only R&D-doing firms are considered, the shares of somewhat important and very important increase substantially, as one might expect. In this case, utility patents are still not as important as trade secrets, but they are now more important than design patents.

Table 3: Importance of different IP mechanisms to US firms (%)

	All firms			R&D-doing firms		
	Not used	Somewhat	Very	Not used	Somewhat	Very
Utility patent	96	3	2	60	15	26
Design patent	95	4	2	67	18	15
Trademark	84	9	6	40	27	33
Copyright	88	7	5	49	25	25
Trade secret	85	8	6	33	22	35

Source: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey 2008. Rows may not sum to 100 due to rounding.

Hence, understanding why firms may prefer alternative methods to protect their IP is at the heart of understanding the functioning of the IP system. If the objective of the IP system is to provide incentives to innovate, an improved understanding of why firms choose to rely on formal IP to protect innovations in some circumstances but not in others has direct implications for the design of mechanisms that set optimal incentives for firms to innovate.

The structure of this paper is the following. Section 2 discusses how the choice between patents and secrecy is analyzed by economic theory while Section 3 summarizes the main results from the empirical analysis. Section 4 is devoted to other types of informal IP while some conclusions are drawn in Section 5.

2. Patents vs. secrecy: Theory

In this section we present the theoretical arguments that suggest why and how firms will choose between formal and informal IP protection. We concentrate our discussion on patents and secrecy as these are the main types of formal and informal IP considered in the economics literature. It is also true that in principle the choice between patents and secrecy involves an explicit and fairly stark tradeoff between disclosure and nondisclosure of an inventive idea. In contrast, consider the traditional use of copyright for protection of software by protecting its expression in bits and bytes. This use is commonly combined with the use of trade secrecy for the code that exists in a form comprehensible by humans, so that in principle no tradeoff exists. That is, a software program can be both published in machine form under copyright and protected by secrecy. The same considerations apply to such informal instruments as lead time and complexity – in principle these can easily be combined with any of the formal mechanisms so there is no real need to choose. However, full secrecy rules out the use of the patent instrument for protecting IP, which is why there is a focus on this choice in the literature.

2.1. Overview of the tradeoff

Table 4 shows schematically the four options available to a firm faced with the decision whether to patent or maintain an invention secret.[11] The table shows that apart from the pure strategies, patenting and secrecy in the lower-left and upper-right quadrant respectively, firms may choose mixed strategies combining secrecy and patenting (upper-left quadrant) or discard both options (lower-right quadrant). Obviously, the mixed strategy in the upper-left quadrant will require some effort to obscure enablement in the patent application.

[11] Of course this assumes that firms have a choice. If for example the invention does not represent patentable subject matter, the option of obtaining patent protection does not arise.

Table 4: Patenting vs. secrecy

	Patent	**Don't patent**
Secrecy	Mixed patent-secrecy strategy	Pure secrecy
Non-secrecy	Pure Patent	Disclosure–publishing

Source: Graham (2004)

Much of the theoretical literature regards a firm's choice between patents and secrecy as mutually exclusive (Friedman *et al.* 1991). The choice is explained by the inherent trade-off between the benefits from using formal IP and its costs relative to relying on informal methods. Benefits and costs are not only a function of the innovation that qualifies for patent protection, but also of defensive or offensive strategic considerations taking into account a firm's competitors' behavior. This is hardly surprising in light of the nature of IP, i.e., its value lies in affecting third parties' behavior rather than directly affecting a firm's own inputs into production.[12]

Applying for a patent requires direct and indirect financial expenditures and a patent may not necessarily be granted; if it is granted, it can lead to 20 years of statutory protection. However, in order to keep the patent in force, maintenance fees have to be paid to each patent office which has validated the patent. Second, a patent also requires full disclosure of information in the patent application (which may be useful to competitors). Third, a patent is only valuable if it can be enforced. Effective enforcement first of all requires validity of the patent right. Second it requires active monitoring of potential infringement and the ability to afford legal action in case infringement is detected. The benefits arise primarily from the ability to exclude competitors from using the technology and the potential to license the patent in exchange for royalty payments. However, it may be difficult for firms to determine the total stream of future expected profits since there is considerable uncertainty attached to the value of innovations (Lanjouw *et al.*, 1998). Patents may also fulfill a number of additional advantages other than the legal right to deny third parties the use of an invention, such as signaling of the quality of an invention to potential investors and customers, a generally improved public image by conveying technological leadership through large patent portfolios, deterrence of infringement suites, an increase in bargaining power in (cross-)licensing negotiations, the ability to participate in patent pools, the possibility to signal to potential research collaborators expertise in a specific area, or to block (entry of) competitors by restricting their freedom-to-operate.

[12] A firm's own freedom to operate is ensured by blocking third parties from claiming property rights on a specific invention.

Obviously, costs and benefits associated with patenting have to be evaluated relative to the available alternatives, such as secrecy. In contrast to patents, secrecy can potentially protect the invention indefinitely. Moreover, secrecy can protect work in progress, whereas only inventions that have reached a certain stage of development can be patented as certain requirements for patentability have to be met. Secrecy is also applicable to a much broader range of inventions than patents, as there is no restriction like that of patentable subject matter. Secrecy does also have costs, since it is vital that confidentiality agreements are used and the knowledge of the invention is guarded. Enforcement of secrecy will also be costly and may be difficult to achieve in court. More generally, keeping innovations secret usually requires active knowledge management in the form of an internal secrecy policy, which may be costly to implement and maintain. For example, firms may rely on the splitting of R&D into different components across researchers and research labs such that individual pieces of R&D do not allow a complete understanding and functioning of a given technology.[13] Also, mobility of key technical personnel may hinder the usefulness of secrecy as a way to protect a firm's IP.[14] Finally, a key issue is whether the invention is easy to reverse engineer and can be done in a relatively short time. If it is, then patent protection may be preferred since secrecy cannot prevent imitation (i.e. if the imitator uses reverse engineering to re-invent the product or process).

While we have described the choice between patenting and secrecy as a mutually exclusive decision, the upper-left quadrant of Table 3 suggests the possibility that formal and informal methods may in fact be combined to protect an invention. Arora (1997), for example, documents the early days of the organic chemical industry which provide an example of a situation in which firms resorted to both secrecy and patenting to protect innovations. Arora argues that certain chemical innovations were composed of tacit elements, notably the specific combination of different compounds, which were protected by secrecy, and codified knowledge, i.e., individual compounds that were protected by patents. Arora argues, more generally, that knowledge based on "inductive and empiricist procedures" is hard to protect through patents because this type of knowledge is hard to codify and the corresponding claims would have to be narrow

[13] Zhao (2006) provides empirical evidence that multinational firms tend to split knowledge more if part of the research is executed in countries with weak IP rights protection. A rather low-tech product also illustrates this point: Thomas's English Muffin. A recent US court case suggests that Thomas splits the recipe of its English Muffins, which is a trade secret, into separate components, such as the basic recipe, the moisture level of the mixture, and the baking process. Reportedly only seven key employees know all steps required to make the muffins while all other employees only have knowledge about their specific assigned task in the manufacturing process. This case also serves to illustrate the threat to secrecy that emerges from the movement of personnel, as the court case was triggered by concerns that one of the seven "informed" employees might reveal his knowledge after having accepted a job with the competitor. See New York Times, August 6, 2010.

[14] See Moen (2005) on this point. Also see Marx *et al.* (2009), who find that a shift towards enforcement of non-compete agreements in Michigan in the mid-1980s decreased inventor mobility by 40 per cent.

which would disclose a great deal of information. Hence, according to Arora, for such inventions firms prefer to patent the codified aspects and to keep the remainder secret.

Graham (2004) studies the case where firms combine patenting and secrecy by staging the revelation of information, keeping the codified part of an invention secret while preserving the option to obtain patent protection in the future. He observes that in the US patent system prior to 1999, patent applications remained secret until the patent issued.[15] By using a continuation, continuation-in-part, or a division, assignees were thus able to keep a pending patent application secret for an extended period of time while maintaining the early priority. In this way, firms were able to effectively combine the benefits of patent protection with trade secrecy and to avoid the trade-off between patent protection and disclosure. Prior to 1995, when the term of the patent was 17 years from the grant date rather than 20 years from the application date, there was little cost in terms of length of patent term to this strategy. Graham suggests that the combination of secrecy and patenting through continuation was particularly interesting to firms that had a first-mover advantage in new technological fields in which the incumbents were threatened by entry that could displace the incumbent's technology. However, if lead-time is important, Graham argues that firms were less likely to use secrecy and continuation due to the fact that lead-time and secrecy are substitutes. Hegde *et al.* (2009) argue that firms may still combine secrecy with patenting to some extent because continuations still offer the possibility to alter individual claims thereby effectively extending secrecy with regard to specific claims.[16] In case of the EPO, van Zeebroeck *et al.* (2009) argue that firms may also be able to effectively hide inventions by increasing the complexity of their patent filings employing divisionals and even by increasing the sheer volume of documentation that accompanies the patent application.

The final cell of Table 3 contains the case where firms choose to simply disclose an invention, for example in the form of a defensive publication, without having recourse to patent protection.[17] Defensive publications may be used in particular strategically by firms to influence the state of prior art relevant to competitors' patent applications (Baker and Mezzetti, 2005). Hence, disclosing previously unknown information to the

[15] If a patent was filed at another patent office that published patent applications after 18 months (counting from the application date), such as the EPO, the patent application would have been published before the patent was granted at the USPTO.

[16] Quantitatively, continuations have been widespread among USPTO applications, even in the absence of pre-issue secrecy. Using approximately 1.25 million granted US patents for the period 1975-1994, Graham finds 20% to have a continuation, division, or continuation-in-part. Hegde *et al.* (2009) find nearly 30% of all granted patents between 1981-2000 are a result of continuations, although the rate fell substantially after the 1995 change to the patent term, and the patents for which continuation was used became of lower technological value.

[17] Henkel and Lernbecher (2008) collect information on the use of defensive publications from interviews with IP managers from 37 large companies and examiners and judges at the EPO and patent attorneys. Their data suggests that defensive publishing is widely used by firms. Their evidence suggests that firms choose defensive publications over patents to avoid the costs associated with patenting, or in situations in which it is unclear whether the innovation is patentable or its expected value low.

public can raise the inventive step threshold, jeopardizing competitors' patent applications (this argument is also made theoretically by Ponce (2007) discussed further below). In contrast to secrecy, defensive publications still guarantee a firm's freedom-to-operate and *de facto* secrecy may even be maintained as the information that is revealed can be restricted or substantially disguised.

2.2. The role of uncertainty

Early literature on the choice between patents and secrecy rests on the specific assumption that a patent application is granted with certainty. This is not always the case. Being granted a patent is an uncertain outcome of a long process and inventors and applicants tend to factor in this uncertainty. Uncertainty can take different forms. The most obvious source of uncertainty related to the patenting process is the outcome of the patent application, which may not necessarily be in line with the applicant's expectations; second, even if the patent is granted, uncertainty remains with regard to the outcome of a civil action for infringement of a patent right, so much so that some authors prefer to talk about probabilistic rights when discussing the legal rights that a patent grants to a firm (Lemley and Shapiro, 2005). In other words firms may have a patent granted but this does not necessarily imply that they will be able to successfully defend their IP in court. Unsurprisingly then, as one of the main benefits of having a patent granted becomes less important, firms may prefer secrecy to patents, ceteris paribus.

To understand how this happens, consider an environment with weak patent protection where the inventor has the best information on the expected value of the invention and a second firm learns about the invention either through the patent or once the related innovation is launched on the market. In this setting, the key decision a firm has to make is how much to disclose and how much to protect, in an environment where property rights are not perfect. Anton and Yao (2004) show that under these assumptions only small and medium value inventions are patented. Further, small patented value inventions are not imitated (the competitor sees no profit from risking infringement), whereas medium value patented inventions may be licensed to others. Also there is a possibility that large inventions would only be protected by secrecy (especially when property rights are weak). Anton and Yao (2004) point to the example of the Ford Motor company in 1913, after introducing the moving assembly line process. Ford encouraged wide disclosure of this innovation, which was not patent protected, but according to Hounshell (1984), the disclosure was insufficient to allow full imitation. The basic rationale was that Ford wanted to signal to competitors that it had extremely low production costs in order to discourage them.

There are also other sources of uncertainty involved in the patenting process: even if it is granted, uncertainty remains with regard to the outcome of a civil action for infringement of a patent right. In this case, in choosing between patent and trade secrecy, firms have to balance three factors: a) the patent strength, defined as the probability that the right (i.e. the patent claims) is upheld by the court; b) the cost competitors have to incur to imitate a patented innovation relative to the cost of imitating a 'secret' innovation; and c) the 'innovation size'. Building on Anton and Yao (2004), but assuming that there is no information asymmetry between inventor and imitator, Encaoua and Lefouili (2005) model the interplay among these three factors and show how they can give rise to various outcomes. For example, choosing to patent may expose the innovator to imitation but the imitation level may be higher or lower than in the case of secrecy. This is because the imitation level not only depends on the imitation cost, but also on two other crucial parameters: the innovation size and patent strength. So competitors may find it too risky to imitate a patented invention whose associated cost reduction is too small.

At the same time, the innovator may decide to patent for strategic reasons. Indeed, it may also be that he can benefit from being imitated: this occurs whenever the incurred loss due to imitation is overcompensated by the damages it receives from an imitator (which depends on whether the court upholds validity *and* finds infringement and, of course, damages are awarded). Therefore, Encaoua and Lefouili (2005) argue that if patenting and secrecy lead to the same imitation level (for a given innovation size and patent strength), then patenting will be strictly preferred to secrecy since damages are expected under the patent regime (i.e. the *damage effect)*. But as soon as imitation levels differ according to the protection regime, this is no longer true as long as imitation becomes higher under the patent regime due to disclosure (the *competition effect)*. One of their key results is that small (process) innovations are always patented since their imitation cost is assumed to be small (and a patent offers some increased protection). In contrast, their model suggests that the most valuable innovations may rely on secrecy. For such large (process) innovations it is assumed that the disclosure from patenting may help imitation (which is highly valuable in the case of a large innovation), similarly to what happens in Anton and Yao's model (2004). Note that in these models the innovation concerned is a process innovation, hence secrecy can be more effective, and the results seem unlikely to transfer directly to product innovations.

2.3. Competition, signaling, and the trading of knowledge

The initial discussion on the choice between secrecy and patenting does not make any direct assumption on the state of competition between innovators or on the product market. However, as increasing empirical evidence suggests (discussed in detail in Section 3), patents are often used for strategic reasons rather than for the simple exclusion of imitators. Theoretical models have started to analyze how competition affects the choice between patents and secrecy. Of course "competition" in this context has several meanings, of which three have been modeled in the literature: competition among innovators, competition between an innovator and imitators, and competition among end users of the innovation/invention.

Some models have focused on the impact of competition between innovators on the choice between patents and secrecy. Horstmann *et al.* (1985) stress the fact that when inventors patent, they reveal information about the value of the (potential) innovation, as well as technical characteristics in the patent document. Such information can be valuable to competitors that want to imitate or invent around. These authors find that "the propensity to patent will be lower the more profitable (ex ante) a competing product is expected to be." (Horstmann *et al.*, 1985: 839). This intuition is further explored below.

Another aspect of competition in innovation is the likelihood of simultaneous discovery. Kultti *et al.* (2006, 2007) focus on situations where this occurs, motivating their work by the famous example of Alexander Bell patenting the telephone two hours before an identical patent was lodged (by Elisha Gray). When there is a strong likelihood of simultaneous invention, Kultti *et al.*'s model indicates that patenting takes on a defensive role: now the choice is not between patenting and secrecy, but between patenting and allowing a competitor to patent. If a firm opts for secrecy there is a risk that its competitor will be awarded the patent instead. Since the patentee always earns higher profits there is an incentive to patent.[18] This type of result has similarities with the older patent race models whereby, in a 'winner take all race', firms compete in research (Wright, 1983; Gilbert and Newberry, 1982). Kultti *et al.*'s main result that patenting is preferred remains true even if patenting *per se* offers slightly less chances of protection than secrecy (see Kultti *et al.*, 2006: 83). However, this result only holds if the protection offered by the patent system is above a certain threshold: indeed, if the protection from patenting falls (say due to weak enforcement), then at some point secrecy will still be preferred. Hence, as is to be expected, no single factor dominates the decision to patent.

The conclusions of Kulti *et al.* may not necessarily hold if one of the firms has a sufficiently large technological lead. For instance, Zaby (2010) analyzes a firm's choice between patents and secrecy in an asymmetric duopoly model. Her model consists of two competitors: one firm is a successful inventor while the second firm is not but may eventually develop the capability of making a closely related invention. The first firm has to decide whether to patent or not. While a patent may protect the firm's invention, the firm may run two additional risks: first, a patent requires the disclosure of the protected invention; second, the competitor may still enter the market with a non-infringing product. In this environment, the technological lead of the inventor is a key factor: indeed, if it is rather large, the first firm may prefer not to patent and use secrecy.

[18] This incentive is also affected by the legal situation surrounding 'prior user rights'. These are the rights given to the original innovator if he relied on secrecy but a subsequent imitator obtained a patent on the innovation.

The choice between secrecy and patents is more nuanced in environments where innovators compete in a sequential fashion, and prior user rights are not recognized and protected by the legal system. The first innovator may decide to patent but then they run the risk of being imitated. However, if the first innovator waives its patent rights and decides to keep its innovation secret, they may end up in a situation where the second innovator discovers the same invention and obtains a patent that excludes the previous innovator from using it. Ponce (2007) suggests that in this situation the first innovator has the incentive to disclose his knowledge, as patents are evaluated on the basis of the prior art and therefore the second innovator may not be granted a patent on a similar innovation. In contrast to the results of Kulti *et al.* for competition in innovation, Ponce finds that the degree of *product market competition* may affect the degree of disclosure as first innovators can disclose a large amount of knowledge if the degree of such competition is not too high.

The models so far do not allow for the possibility of knowledge being traded, i.e., for the innovator to sell the knowledge required to use his invention. Henry and Ponce (2011) analyze a set-up in which an inventor can sell specific knowledge on an invention to potential imitators and these potential imitators have the choice between costly imitation and acquisition of the knowledge. In equilibrium, inventors choose to sell their technology in a way that allows acquiring firms to re-sell the knowledge to other firms. As a result, once the first imitator has acquired the knowledge and entered the market, he will compete with the innovator in the market for knowledge and drive prices for the knowledge to zero. This is nevertheless optimal for the inventor because potential imitators do not immediately enter the market, but wait in the hope that another firm enters first and drives down the price of the required knowledge. Hence, this produces a situation in which the inventor enjoys a temporary monopoly position without recourse to a patent. The model implies that the more tradable is knowledge holding the patent term life constant, the more likely firms are to rely on secrecy rather than patents (assuming patenting is more expensive than maintaining an invention secret). The intuition behind this is that the certain length of the protection granted by a patent has to outweigh the relative costs associated with patents because inventors can also reap monopoly profits from the delayed entry of imitators. In practice, however, it appears that firms find patents convenient when constructing knowledge contracts.

Anton and Yao (1994) focus on competition in the end user market (rather than competition from other inventors or imitators) and consider a small, independent inventor who is unable to secure property rights on his invention because it is too small or not eligible for protection. The invention is assumed to be pivotal to a process innovation that is important for two competing large firms. Their model indicates that rivalry between the two large firms will ensure that the inventor can always obtain some return on an invention (i.e. each firm wants to sign an exclusive contract with the inventor). This is an example of how the nature of competition in the end user market can drive returns for inventors. However, in their model a patent turns out to be irrelevant since they assume only two end users and that negotiation works well with or without a patent (i.e. even without a patent the inventor can negotiate and sign an agreement using trade secrecy law). Hence, the inventor can use a patent (and licensing based on the patent), or rely on secrecy and use confidentiality agreements (with license payments). More generally, while holding a patent may give more leverage in negotiations, patents can be infringed, hence whether patents or trade secrecy are equivalent is an empirical matter.

2.4. Cumulative innovations, patent fences and thickets

The original models of secrecy and patenting assume that innovations are discrete and use a one innovation-one patent model. However, in reality innovations are often complex, involving many inventions covered by patents and also cumulative (or sequential), i.e., inventors build on the innovations of others. At a very basic level, in industries where innovation is cumulative, secrecy can lead to duplication of efforts. For example, Erkal (2005) obtains this result in a model with two sequential innovations (each one involving a race between two innovators). The key assumption of the model is that if the first innovator relies on secrecy, then the subsequent innovators do not have as much knowledge, which unsurprisingly does lead to duplication of efforts. Thus in cases where sequential innovation is important and there are several innovators, she argues that it may be worthwhile increasing the breadth of patent protection (since this will encourage the use of patents and associated disclosure).[19]

The cumulativeness of modern innovation has lead to two different patenting strategies: "patent fences", which are more often associated with "discrete product" industries like chemicals and pharmaceuticals; and "patent thickets", associated with "complex product" industries such as information and computing technologies. Cohen *et al.* (2001) contains a useful discussion of the distinction between the two types of industry and von Graevenitz *et al.* (2011) suggests a measure based on patent citation behavior among firms that can be used to identify technology areas as discrete or complex.

Patent fences occur when a firm patents a number of close (product) substitutes, perhaps different versions of a product that are invented over time, preventing other firms from entering the particular technology area. This kind of situation, where multiple substitutes can co-exist but where they rely on separate patents, are characteristic of 'discrete product' technologies and industries.[20] Such a strategy has several purposes: a sequence of patents at different dates may prolong the period in which a firm enjoys monopoly power for a particular product and having many patents for the same product or related products raises rivals' cost of search and opposition as

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[19] Other papers that consider similar models include Denicolò (2000) and Denicolò and Franzoni (2004a).

[20] Schneider (2008) gives the example of Du Pont Corporation during the 1940s, which had patents on 200 substitutes for Nylon.

well as simply excluding them from entering the area. Levin *et al.* (1987) are the first to clearly identify chemicals and pharmaceuticals as industries of this kind from survey evidence.

In complex technology industries large patent portfolios can also emerge, but for somewhat different reasons. In these industries, due to the need for interoperability and standards, a single product may require many (sometimes thousands of) patents, often held by a large number of firms. The semiconductor and electronics industries have attracted attention as industries where such patent thickets may occur (Grindley and Teece, 1997). Importantly, producing any product may require the licensing of a competitor's patents, hence there is a strong strategic value in owning a large patent portfolio since this gives leverage in negotiations over cross-licensing of patents (Hall and Ziedonis 2001).

For our purposes we are interested in what these issues imply for the choice between secrecy vs. patents. Let us initially consider 'discrete product' industries and patent fences. In these cases can use of secrecy ever be rational? This is a question that Schneider (2008) asks using a model where there is cumulative innovation. He assumes that there is one lead innovator and one potential follower innovator. If the follower innovates, the two products compete. The follower only tries to innovate if they expect to make profits, which depends on the cost of R&D and nature of competition. This gives rise to the possibility that the lead innovator could choose to keep an invention secret in order to prevent disclosure, which will raise the cost of the follower's R&D. Schneider's model suggests that this is only rational "when the speed of discovery [of the lead innovator] of the subsequent invention is high, relative to the competitor's" (Schneider, 2008: 1349). In other words, the lead innovator has the ability to generate a series of new products and secrecy prevents a competitor entering the race. This conclusion is essentially the same as that in the previously cited Zaby (2010), which also presents an asymmetric duopoly competing for innovations. Both reach the conclusion that firms with a large technological lead over their competitors may prefer secrecy to patenting.

With regard to patent thickets, even when there is cumulative innovation it would appear that the need to cross-license is paramount, hence secrecy is unlikely. In most ICT industries firms rate patents as relatively unimportant for securing the returns to innovation and yet they patent heavily. Hall and Ziedonis (2001) call this the "patent paradox" in the semiconductor industry and state, "the gap between the relative ineffectiveness of patents (as reported in surveys) and their widespread use is particularly striking." (Hall and Ziedonis, 2001: 102) The surveys they are referring to are those by Levin *et al.* (1987) and Cohen *et al.* (2000). Kortum and Lerner (1999) identified improvements in the management of R&D as the primary reason that patenting in the U. S. surged in the late 1980s and 1990s when compared to R&D spending, but Hall and Ziedonis (2001) point instead to the strategic value of a patent portfolio when negotiating cross licenses. Hall (2005) shows that the growth in patenting at the USPTO during this period is entirely accounted for by firms that are in the ICT industry but that patent in all technologies. This result suggests both the fertility of that sector and the fact that interoperability and cross-licensing have become increasingly important, diminishing the rewards to secrecy vis-à-vis patenting. A recent symptom of this phenomenon is the highly publicized race between Apple, Microsoft, and Google to acquire the telephony and network patents of Motorola and Nortel referred to in the Introduction.

2.5. Disclosure and social welfare

The empirical fact that many firms choose to use secrecy rather than patents has prompted various theoretical models that analyze the impact of this choice on social welfare. In our context, one of the issues at stake concerns the role of disclosure, where here this is defined as the full description of the invention contained in the patent document. One of the basic rationales of the patent system is to encourage disclosure, since this prevents the duplication of research and, once the patent has expired, allows 'those skilled in the art' to quickly replicate the invention. This rationale is referred to as the *contract theory* of patents by lawyers, as opposed to the *reward theory* (which focuses on incentives to invent). The role of disclosure in contract theory is very specific: prevent duplication and allow rapid diffusion once the patent has expired.

In several of the surveys mentioned previously, firms or inventors were asked for a qualitative assessment as to how important patents were as a source of information for a particular invention. Cohen *et al.* (2002) find that US companies generally prefer other sources of information over patents. Moreover, Arora *et al.* (2008) find that these measures are not related to spillover effects, a finding which suggests that there are productivity gains from patent disclosure. Walsh and Nagaoka (2008) find large differences in the importance of patents between US and Japanese inventors, with Japanese inventors about twice as likely to use patents to acquire information. In line with the prior studies, Gambardella *et al.* (2011) find that patents are particularly important sources of information in a small number of technical areas, such as polymers, organic chemicals, pharmaceuticals, petrochemical and materials chemistry, and that Japanese inventors assign greater importance to information in patents than either European or US inventors.

Two theoretical models of the disclosure incentive use contract theory in order to focus attention on the role of disclosure.[21] The model of Denicolo and Franzoni (2004b) considers a drastic process innovation (i.e. one that dramatically reduces the cost of production). There is a lead innovator and an imitator. The main result is that patenting improves social welfare, mainly by reducing the duplication of research. To be clear, the problem with secrecy is that competitors re-invent at considerable cost.

[21] "In order to disentangle the disclosure from the reward motive for granting patents, we assume that the innovation is the fruit of serendipity." (Denicolo and Franzoni, 2004b: 367).

Cugno and Ottoz (2006) have a similar model to Denicolo and Franzoni but assume that "a market in unpatented technologies does exist" (Cugno and Ottoz, 2006: 211). Again they focus only on contract theory (they assume innovators simply experience a stream of innovations). In their model social welfare is higher when there is no patent system. This is caused by two factors. First, the possibility of licensing reduces the costs associated with duplication of research. Second, as discussed above, a patent system gives firms an option to protect inventions for 20 years while, under secrecy, protection might not have extended for this long. Note, however that the Cugno and Ottoz model ignores any R&D incentive effects, which are the main argument in favor of the patent system, so its applicability is questionable.

The theoretical literature mentioned above assumes that secrecy is a successful strategy so it applies only to some inventions. However, in the cases where reverse engineering is not too costly, the choice between patenting and secrecy is not really much of a choice in the absence of prior user rights. So one relevant question is how much savings an imitator experiences by having access to the information in a patent. Work by Gambardella *et al.* (2011) provides a first set of estimates of cost-savings incurred by follow-on inventors due to knowledge of the patent literature. The data were collected in a large-scale inventor survey covering more than 22,000 inventors in 23 countries. Inventors were asked in this survey to quantify the time saved for the respective invention process when compared to a situation in which the information from patents had not been available. Time savings from disclosures follow a highly skew distribution, with estimated median values of 5.9 hours and mean values of 12.2 hours. There is considerable heterogeneity across technical fields - median values range between 1 hour (digital communication technology) and 36 hours (organic chemicals). Thus in fields where patents have strong impact on appropriability such as chemicals and pharmaceuticals, disclosure effects also appear to matter the most.

2.6. Summary

Table 4 summarizes the different determinants of the choice between patenting and secrecy suggested by the theoretical literature: (a) exogenous differences in technologies, (b) industry demographics and characteristics, (c) strategic/competitive considerations, and (d) institutional aspects. In the next section we will review the empirical evidence on the importance of these factors.

Table 4: Factors affecting the choice between patenting and secrecy

Class	Factors	More likely to patent if
Exogenous differences in technologies	Product vs. process	Product innovation
	Expected commercial life	Commercial life longer?
	Value of innovation	Innovation value lower, c.p.
	Tangible vs. intangible components	Tangible (reverse eng.)
	How effectively does a single patent protect the invention?	???
Industry characteristics	Competition in innovation	More competitors
	Technology gap between lead innovator and imitative followers	Gap is smaller
	Competition between firms is ‘neck and neck’, with each firm building on other firms’ innovations	Other firms patent (cross-license)
	Firm size	Large (lower TC) Small (obtain financing, fewer complementary assets)
Strategic considerations	Complexity of research - tacit vs. codified	Codified
	Patent signals profitable innovation to competitors	Signaling is useful
	Difficulty of reverse engineering	Easier
	High probability of simultaneous invention	Race to be first
Institutional aspects	*Patent system:* Higher initial fixed costs reduce patent use, especially for smaller firms Higher maintenance and enforcement costs reduce patent use Division and continuation - ability to delay and amend patents increases their strategic value Disclosure requirements	
	Trade secrecy system: Costs of confidentiality agreements Internal monitoring and active knowledge management Enforcement issues – availability of non-compete agreements	

3. Patents vs. Secrecy: Empirical Evidence

3.1. Survey evidence

By now we have available survey evidence from many countries that sheds light on the choice between secrecy and legal IP protection tools. The seminal studies in this area are those by Levin *et al.* (1987) – so called Yale I survey - and Cohen *et al.* (2000) – the Carnegie Mellon survey. Neither of these works attempted to directly test the empirical implications from economic theory but both surveys were concerned with the extent to which firms in different industries chose legal and non-legal methods to secure returns from their intellectual property. The findings are broadly consistent across the two studies. On average, patents are not the most important mechanism of IP appropriation while secrecy and lead time are. However, this is not entirely true for product innovations and for industries that are specialized in the production of "discrete" products like pharmaceuticals and other chemicals where patents are still the favorite tool to secure the returns to intellectual property.

At roughly the same time as the Yale I survey (1981-83), Mansfield (1986) surveyed about 100 US manufacturing firms, asking them to what extent patent protection was essential for the commercial introduction of their inventions. He found that in two industries, pharmaceuticals and chemicals, patent protection was essential for 30 per cent or more of the inventions. In another three industries (petroleum, machinery, and fabricated metals), patent protection was essential for about 10-20 per cent of the inventions. The remaining seven industries (electrical equipment, office equipment, motor vehicles, instruments, primary metals, rubber, and textiles) showed no reliance on patents. He also found that in the five industries where patents were relatively important, 84 percent of patentable inventions were patented, whereas the share fell to 66 per cent in the industries where patents were not important. His results seem very supportive of those in the Yale I survey.

One of the first studies to follow up on the Yale study was that by Harabi (1995) for Switzerland. He confirmed that Swiss firms also ranked patents very low as a means of appropriating the returns to innovation, except in the chemicals (including pharmaceuticals) sector and some parts of the machinery sector. The firms expressed concern that patents revealed too much information and that it was too easy for firms to invent around them. However, they were viewed by some firms as useful for obtaining licensing income.

Cohen *et al.* (2000) found that firms use patenting for strategic reasons rather than for protecting their intellectual property. Respondents reported that they used patenting to block competitors, to improve goodwill reputation and to improve bargaining power in the market. A similar type of analysis conducted on European firms confirms these overall findings. Arundel (2001) focused on the relative effectiveness of patents and secrecy using the CIS I survey for six EU countries and found that firms systematically regard lead-time and secrecy as more important ways to protect their IP than patents. Over 50 per cent of firms rank lead-time as the most important mechanism to appropriate returns to their innovation and nearly 17 per cent regard secrecy as the most important way to protect an innovation. In contrast, only about 10 per cent regard patents as the most effective way to secure returns and only about 3 per cent consider registered designs as the most important way to exploit an innovation. The relative greater importance of secrecy applies to firms across different size categories, although smaller firms regard secrecy as even more important than larger companies.

Following these early studies, the empirical literature in this field has then evolved into several strands that are currently at different levels of development. The first (and the largest) wants to explain why some firms in some industries are more inclined to use secrecy than others (Leiponen and Byma, 2009; Pajak, 2009). A second one has focused on cross-country comparisons to understand whether the US findings were still valid for other institutional settings (Arundel *et al.*, 1995; Cohen *et al.*, 2002). Finally, a tiny literature (still in its infancy) has started to focus on the impact that the preference for unregistered IP methods has on firms' performance and on the diffusion of knowledge across the economy (Hussinger, 2006; Hurmelinna-Laukkanen and Puumalainen, 2007).

3.2. The impact of firm and industry characteristics

This sub-field of the literature is definitely the most developed and is the one from which it is possible to draw some reasonably robust conclusions about what drives the choice between secrecy and legal IP methods. With the exception of some historical work by Moser (2005, 2011), the empirical analysis has mostly been conducted using data from various Community Innovation Surveys which have the advantage that they identify firms that have a product or process innovation and also contain questions on the use of alternative appropriability methods. While the studies have been conducted on different countries (and therefore different institutional settings), it is interesting to notice that some empirical regularities emerge across the board and that it is possible to identify some characteristics of the industry and the innovative firms that appear to affect the choice between secrecy and patents. These are the following:

Product vs. process innovations: consistent with the early findings for US manufacturing, non US-based studies find that the use of patents is more associated with product innovations than with process innovations. Arundel *et al.* (1995) found that lead time and patents were most important for product innovations, whereas secrecy was most important for process innovations. Also see Hussinger (2006) for German firms and Hall *et al.* (2011) for UK firms.

Size: one of the main findings of the Yale and Carnegie-Mellon surveys is that appropriability strategies vary across firms of different size. There are a number of reasons why the size relationship can be highly variable. Large firms generally find the use of the patent system lower cost per patent than smaller firms for fixed cost reasons. Equally SMEs may suffer from financial constraints and therefore may decide that applying for a patent is too financially onerous. However, firms that specialize in knowledge production and proof of innovative concept are more likely to be SMEs and for these firms patents can be quite important since most of their assets are knowledge assets. In addition, some startups may find that having patents improves their access to financing (Hsu and Ziedonis 2007, *inter alia*).

Not surprisingly a few studies have focused on the choice of IP methods for small firms. By using an *ad hoc* survey of 936 Finnish SMEs, Leiponen *et al.* (2006) find that small firms find informal means of protection, such as speed to market or secrecy, more important than patenting. One key result however is that cooperation greatly influences the choice of intellectual property strategy for SMEs. Indeed, SMEs that cooperate in innovation with horizontal partners or significantly depend on vertical partners tend to prefer speed, whereas process innovators with modest R&D investments or few cooperative R&D activities display a preference for trade secrets. Only SMEs with university cooperation—typically R&D intensive and science-based small firms—rank patents as the most important method of appropriating innovation returns in their field. This result suggests that firms whose only assets are the intangible results of research find formal property rights on those assets more valuable than firms with other means of protecting the assets.

However, not all SMEs are equal. Indeed, among SMEs, start-ups tend to be a group of their own and not surprisingly may have appropriability strategies that are different from those of established small firms. The most comprehensive evidence of start-up patenting comes from the 2008 Berkeley Patent Survey conducted by the Berkeley Center for Law and Technology. Graham *et al.* (2010) and Sichelman and Graham (2010) summarize the evidence from the information obtained on 1,332 high-tech (bio-tech and software) start-ups founded in the US since 1998. In particular they note important differences in patenting behavior and the way in which patents are used across industries. While for some industries, such as bio-tech, patenting is a vital part of corporate strategy, firms in other sectors, notably software, essentially avoid the patent system altogether. They also point out that strategic motives to patent as described above are important for start-ups, contrasting the commonly held view that strategic patenting is only practiced by large enterprises: indeed start-ups value the reputation effect that patent ownership may bring about. The survey also asks firms directly why they choose not to patent and it turns out that the most significant barrier to patenting (across the two industries) is financial. However, bio-tech firms rate concerns about the disclosure of information contained in a patent publication as a greater obstacle than costs while the opposite is true for software. To some extent this difference reflects the differing use of the system by firms in the two areas: bio-techs worry about disclosure because they *do* patent (in spite of the cost), whereas software firms worry more about cost because they *don't*.

Hsu and Ziedonis (2007) find some evidence that patents can act as a 'signal' of a start-up's technical proficiency and innovativeness, using 370 U.S. start-up semiconductor firms. These firms were involved in 800 rounds of financing over 1980 to 2005. They find "a doubling in patent application stock associated with a 24 per cent boost in funding-round valuations beyond what would otherwise be expected." Mann and Sager (2007) look at start-ups in the software sector and find that even though only a quarter of these firms have any patents, those that do progress through the venture capital rounds of financing more successfully and exhibit better performance.

Overall, however, most studies with a full range of firm sizes find that the patenting propensity rises with size, other things equal (Arundel 2001; Hall *et al.* 2011). Jung and Walsh (2010) find important differences in the patenting behavior between small and large firms by using data collected by the Georgia Tech Inventor 2007 Survey (Jung and Walsh, 2010) on US-inventors of triadic patents (those taken out at the USPTO, EPO, and JPO). In this survey, small firms appear to use patents more to commercialize an invention, to obtain licensing income and to enhance their reputation. In contrast, large firms are found to engage in patenting more for strategic purposes and to cross-license IP. In fact, Jung and Walsh find that nearly three quarters of surveyed inventors indicate that blocking was a major determinant in the decision to patent. Licensing and cross-licensing are considered to be important by only about a quarter of respondents.

R&D intensity: not surprisingly, patenting is associated with the R&D performance within firms. In general, it is roughly proportional in the cross section of manufacturing firms (Bound et al. 1984), but somewhat less than proportional within firm (Hausman et al. 1984). Studies that look at the choice between patenting and secrecy for protection of innovation generally find that R&D-performing firms are more likely to opt for patents (presumably because they are more likely to have patentable inventions, e.g., Hall *et al.* 2012). The numbers in Table 3 for US firms clearly confirm this fact.

Incremental vs. large innovations: Economic theory suggests that firms which produce large innovations should rely more on secrecy than on patents to protect their IP (see for instance the paper by Anton and Yao, 2004). While it seems counterintuitive, this result is based on the idea that the disclosure requirement of the patent law may allow competitors to appropriate some of the returns of the innovation while at the same time patent-holders may not necessarily have their rights protected in courts. Therefore, the larger the expected profitability of an innovation, the less keen a firm is to patent it; instead the firm opts for secrecy. This hypothesis has been tested in a paper by Pajak (2009) who uses the French version of the CIS 4 to model the choice between patenting and secrecy where the size of innovation (i.e. whether the innovation is new to the market or only to the industry) appears among the independent variables. He finds the rather equivocal result that in one third of innovative industries (7 out of 21) a larger innovation leads to a smaller patent-to-secrecy ratio, in line with the predictions of Anton and Yao (2004), although for the other two-thirds, a larger innovation favors patenting over secrecy. Moreover, for his sample of small firms in intermediate goods sectors, Pajak finds that firms reporting innovations new to the firm are more likely to use patents, whereas the same firms seem to prefer secrecy for inventions new to the market. This empirical finding should be interpreted with caution, however, as the sample size is small (72 firms) and the share of innovating small firms is less than 10 per cent (that is, only 7 firms)

Competition: Again a large body of economic literature suggests that competition (meant as competition among innovators or competition among the users of the innovation) should affect the choice of the IP mechanism. In spite of its obvious importance, few studies test the impact of competition on the choice between secrecy and patenting. An exception is an unpublished paper by Farooqui (2009) who, by using a panel from three waves of the UK CIS covering the period 1998-2006,[22] finds that firms in more competitive sectors (proxied by import intensity) tend to use more legal IP methods (i.e. patents and trademarks).

Multinational status: While the economic theory is silent about the impact that ownership has on the choice of the IP, it is possible to argue that multinationals protect their intellectual property in a different way than national firms: for instance, they may favor legal IP methods over non-legal ones for strategic reasons and use a different mix of legal and non-legal methods according to the differences in patent laws across countries. They are also more likely to confront difficulties with keeping innovations secret due to the location of plants in multiple countries and the consequences of a larger span of control. Only Farooqui (2009) has tested the impact of the multinational status on the IP methods mix and he found that indeed multinationals prefer legal IP methods over alternatives. His regression also included size controls, so the result was not simply due to the size of the firm.

Financial Constraints: Applying for a patent and managing a patent portfolio is expensive. A firm not only has to meet the direct monetary expenses associated with the application process but it also has to monitor the market for potential infringement and take legal action. Not surprisingly firms that report that they are financially constrained tend to use unregistered IP methods. As discussed earlier, the most important reason cited by startups for not patenting is cost (Graham *et al.* 2010). See also Cordes *et al.* (1999), who report on a survey of small high technology firms done for the US Small Business Administration which found that cost of applying and enforcement was the leading reason these firms did not generally use patents.

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[22] Farooqui (2009) uses CIS3 (1998-2000), CIS4 (2002-2004), and CIS5 (2004-2006).

Knowledge management practice: Jensen and Webster (2009) use survey data on a set of 785 Australian firms to understand the interaction between firms' knowledge management practices and their choice of knowledge appropriation mechanisms. They find firms that pursue a "closed learning style" to rely more on patents and secrecy. Whereas firms that base their technological learning on a more open model that involves exchange across firms are more likely to rely on lead time, brand names, and control over the distribution process. This provides additional evidence that patents and secrecy can act as complementary forms of knowledge appropriation mechanisms within a "closed" knowledge management model that relies on the acquisition of knowledge through licenses, the reading of (patent) publications, and in-house R&D.

3.3. Cross-country comparisons

Most empirical studies have been conducted on firm-level data for a single country; while this allows researchers to identify the firms' and industry characteristics that can explain firms' preference for secrecy (or for patents), single country studies do not allow the identification of the characteristics of the patent legislation that can influence this preference. For instance, in countries where the procedure to apply for a patent is very cumbersome, some firms may find the whole process so expensive they prefer to opt for secrecy to protect their IP. Some researchers have used cross-country data (or international data surveys) to understand how the national patent legislation can affect the choice between patents and secrecy. We focus here on the PACE survey, developed by Arundel *et al.* in 1995 and also on the mid-nineties surveys of Japanese and US firms (Cohen *et al.* 2002).

The PACE was directed to the European Union's 840 largest manufacturing and industrial firms located in Germany, the UK, Italy, Belgium, the Netherlands, Luxembourg, Spain, Denmark, and France. The findings of the PACE report confirm important industry variations regarding the effectiveness of IP protection tools for European firms. As in the case of Levin *et al.* (1987) and Cohen *et al.* (2000) for the U. S., patents play an outstanding role in the pharmaceutical and chemical industry for both product and process inventions. Secrecy is important in protecting process inventions in most industries. Arundel *et al.* (1995) suggest that differences in IP legislation and enforcement can explain why European firms tend to use a different mix of IP tools than US firms.

Cohen *et al.* (2002) compare results from a survey among 593 Japanese and 826 US firms regarding the importance of patents as appropriability mechanisms. It emerges that slightly more respondents in Japan rated patents as an effective means to protecting innovations than in the US (38 per cent and 36 per cent respectively for product and 25 per cent and 24 per cent respectively for process innovations). The more striking result is that secrecy is regarded as a much less effective way to protect innovations in Japan than in the US (26 per cent and 51 per cent respectively for product and 29 per cent and 53 per cent respectively for process innovations). Hence, while in the US other appropriability mechanisms, above all secrecy and lead time, are regarded as the most effective ways of protecting innovations, in Japan, patents are equally important as any of the other mechanisms. The authors explain these differences in the importance of patents in Japan and the US by institutional differences in the countries' patent systems. For instance, at the time of the survey, patent laws allowed innovators to apply for a patent early in the innovation process in Japan due to a first-to-file rule of priority (as opposed to the US first-to-invent rule of priority). Also, Japanese patents were subject to "pre-grant opposition" while no analogous opposition process existed in the US. These differences implied that Japanese firms rated patents as a stronger tool to protect their IP.

3.4. Impact on Performance and Knowledge Spillovers

A small literature is beginning to focus on the impact that the choice of IP instrument has on the firms' performance. It is not very developed and while issues associated to the identification strategy are still unresolved, it is still interesting to report on some early results that can offer guidance for future empirical analysis. Hanel (2008) analyzes the use of IP protection for the Canadian manufacturing industry, paying attention to a possible effect on profits. As a first step, he focuses on the propensity of innovative firms to protect their IP. Small firms use IP protection tools less often, whereas world-first inventors use every kind of IP protection more frequently than other firms. In the second stage he focuses on the impact that the use of IP protection has on the firms' profits. He finds that firms which protect their IP increased or maintained their profit.

Hussinger (2006) uses 626 manufacturing firms from the Mannheim Innovation Panel (1998-2000, CIS III) to analyze the impact on the percentage of sales of new products of the use of patents and secrecy. There is a strong positive correlation between patents and sales with new products, whereas there is no relationship between secrecy and innovative sales. This finding is consistent with the hypothesis that patents are preferred to secrecy for protecting valuable inventions in the market phase, but is not supportive of the several models that suggest that smaller rather than large inventions will be patented. This paper is noteworthy for the fact that the author uses lagged patent holdings as an instrument for the firm's current evaluation of patent importance, controlling to some extent for the endogeneity of the choice of IP. Unfortunately she is unable to look at process innovation due to the lack of outcome data on cost reduction due to innovation.

Hurmelinna-Laukkanen and Puumalainen (2007) examine the efficiency of different appropriability mechanisms among a sample of 299 Finnish companies, mainly in manufacturing. The mechanisms included various forms of formal IPR (patents, copyright, trademarks, design etc) as well as contracts and labor legislation, tacitness of knowledge, lead-time, secrecy and human-resource management (HRM). Lead-time and practical or technical means of concealment (corresponding roughly to secrecy within the firm) were viewed as being the strongest mechanisms, followed by tacitness and contracts. Formal IPRs, labor legislation and HRM approaches were viewed as the weakest means to appropriate returns to innovation. This may be due to the fact that the principal question here related to preventing imitation by competitors. This study is possibly unique in trying to relate the firms' strategic goals on appropriability to the utilization of different mechanisms. For example, there was a positive relationship between pursuing short-term value and the use of lead-time, but formal IPRs did not seem to be used for this. Surprisingly, there appeared to be no support for the hypothesis that the more a company concentrates on preventing imitation, the more it uses tacitness to protect knowledge – indeed, there was some suggestion of firms favoring explicit IPRs for this process. Overall, these results point towards some endogeneity between firm strategies and their IPR regime "our findings suggest that the appropriability regime of a firm is dynamic by nature: the availability and strength of the mechanisms have an effect on their usage, and the strategy of the firm also guides the formation of the regime" (Hurmelinna-Laukkanen and Puumalainen, 2007: 107).

In recent work using Community Innovation Survey data together with the actual patent holdings of a large sample of UK firms, Hall *et al.* (2012) showed first that a preference for patents over secrecy is associated with taking out patents, not surprisingly. They then go on to demonstrate that owning patents is associated both with a greater share of sales from products new to the market but not from products new to the firm and also with higher employment growth rates in the firm. Hall and Sena (2011) use the same data to show that a preference for formal IP, coupled with innovation, has a large impact on productivity, whereas a preference for informal IP has no such effect. Although these results suggest that formal IP (especially patents) is associated with greater appropriability at the firm level, because we are unable to control completely for invention or innovation quality, strong conclusions are not yet warranted.

Finally, Schmidt (2006) focuses on knowledge spillovers and tests in particular whether secrecy can hamper the diffusion of knowledge spillovers. The empirical analysis has been carried out on the German version of the Fourth Community Innovation Survey (2002-04) and unsurprisingly, he finds that secrecy does decrease knowledge spillovers to other firms in an industry and consequently poses obstacles to their innovation activities.

3.5. Indirect evidence

The literature discussed so far employed survey data that contain detailed information on firms' self-reported innovative activities, output, use and valuations of different formal and informal IP protection mechanisms. In parallel to this, there are also a few studies that uncover innovators' reliance on formal and informal IP indirectly by employing exogenous differences in the legal protection of formal and informal IP over time and across jurisdictions.

Moser (2005) exploits such exogenous differences in the availability of patent protection across countries in the 19th century. Moser looks at innovations presented at two world fairs (London in 1851 and Philadelphia in 1876). Some of these innovations were patented and some were not, which was partly a result of the fact that not all countries had patent laws at that time (Switzerland and Denmark in 1851 and Switzerland and the Netherlands in 1876). Her findings suggest that patent protection is not critical to innovation but it does have a strong effect on the industrial distribution of innovative activity. Countries without patent protection tended to concentrate in industries where secrecy was effective (as reverse engineering was not so easy and law protected trade secrets). Textiles, food processing, scientific instruments and watch making were examples; and countries such as Switzerland, which had no patent system, concentrated in these industries. In contrast, innovations from the US (which had a relatively low cost and effective patent protection and a patchy way of protecting trade secrets) concentrated in machinery. The Netherlands abolished its patent laws in 1869 and this led, according to Moser, to a substantial increase in innovations coming from food processing where secrecy was important. In other words, lack of an IP system (or a weak one) does not stop firms from innovating but can have implications for the direction of innovative activity.

Png (2011) provides an example of analysis of the impact of secrecy on R&D and the choice between patenting and secrecy without having survey information on a firm's innovative activities or self-reported use and evaluation of formal and informal IP. He uses the NBER Patent dataset, which contains firm-level data for all publicly traded companies in the US manufacturing sector, to assess the impact of a strengthening of legal protection of trade secrets through enactment of the Uniform Trade Secrets Act (UTSA). Png finds that enactment of the UTSA is associated with an average drop of 2.4 per cent in R&D among manufacturing firms. However, the figure disguises important heterogeneity across sectors. Whereas the drop is even more pronounced for the medicinal chemicals and botanicals sector (-4.2 per cent), as well as the computer terminals industry (-4.7 per cent), Png does not find an impact in relatively more R&D intensive industries such as pharmaceuticals and computer communications equipment. The results are interpreted as suggesting that own R&D and knowledge spillovers are complements, i.e., an increase in the use of secrecy leads to a decrease of spillovers which leads to a net decrease in R&D given the complementarity of spillovers with own R&D efforts. Png also analyzes the effect of the strengthening of legal trade secret protection on firms' patent filings, but finds overall no discernible impact. However, he finds some evidence that it reduced patenting in sectors in which patents are effective in protecting process innovations. Png interprets these findings as evidence for firms filing patents mostly for strategic reasons, rather than to appropriate returns to an innovation.

4. Other types of IP

Unlike informal methods of IP protection such as secrecy and lead time, the alternative formal methods of IP protection such as trademarks and copyright are not necessarily substitutes for patents, but instead offer the ability to protect different aspects of an innovation. This section briefly reviews the relatively sparse empirical evidence on the use of these methods of protection.

4.1. Trade marks

Trademarks are probably the most widely used method of registered IP protection, as they are available to essentially any firm selling a good or service. In some cases they can represent an extremely valuable and long-lived brand but most end up being of little value or having a relatively short life. Empirical studies into the effect of trademarking on firm performance have been scarce, although this is changing with the advent of computerized data availability at Trademark Offices, notably the Office for Harmonisation in the Internal Market (OHIM) of the European Union. Most of the available studies look at the association of trademark ownership with firm value and typically find that the average trademark is valued positively but by less than the average patent, and also that trademarks are more important to service sector firms.

Seethamraju (2003) analyzed the value of trademarks in 237 US firms over 1993-97, finding a positive role for trademarking on sales and also on market value. Griffiths *et al.* (2011) used a sample of slightly less than 2,700 large Australian firms over 1989-2002 and found that the stock of trademarks was a significant determinant of profits, but with a smaller impact than either patents or registered designs. They also found that the value of a trade mark was rising over their data period. Their work is consistent with the earlier work of Bosworth and Rogers (2001), who had used a sample of 60 Australian firms from 1994-96 and found a positive but insignificant coefficient for trademarks in the market value equation that also included R&D and patents. They also noted that trademarks were somewhat more important to non-manufacturing firms than manufacturing firms.

Greenhalgh and Rogers (2007) analyze a large sample of publicly quoted UK firms from 1996-2000, with both manufacturing and services firms being included. They look at whether any trademark activity, and also the effects of increasing trade mark intensity, impact on performance, as measured by Tobin's q, or the ratio of market value to the book value of the tangible assets. The results indicate that a firm's stock market value is positively associated with trademark activity (as well as with R&D and patents). They find larger differences between firms with and without trademarks in the service sector than for manufacturing. They also find bigger differences in Tobin's *q* when the services firm is applying for European Community trademarks, rather than just applying for UK marks. When looking at intensities (i.e. the ratio of trademarks to assets), they find an increase in the intensity of Community trademarks raises market value for both manufacturing and services, but this relationship weakened over their data period. Since there was an increase in trademarks during the late 1990s, a fall in the estimated value of such activity might be expected. Greenhalgh and Rogers' interpretation of their findings is that, in general, trade mark activity proxies a range of other, unobservable, firm-level characteristics, including innovation that raise productivity and product prices.

Greenhalgh and Rogers (2007) also analyze whether greater trademark intensity raises productivity growth. They find that higher trademark intensity has some positive association with productivity growth in services, but the results are relatively weak for manufacturing firms. These results for the relationship between productivity and trademarks were broadly consistent with those derived for their quoted firm sample using the market value approach, suggesting that stock markets are efficient in estimating the likely benefits of new intangible assets, and that managers are not just seeking trade marks to follow a 'management fad'. Even so, the marginal returns to extra trade marks per firm were diminishing quite rapidly over the period, as indicated by exploration of the interaction of time trends with trade mark intensity, suggesting decreasing returns to further proliferation of product variety.

Empirical evidence on the determinants of trademarking is similarly sparse. Jensen and Webster (2004) consider the increase in trademarking in Australia from 1976 to 2002. They find that the increases are associated with a) increasing globalization b) the growth of household income c) an increase in service sector activity and d) that trademarking appears linked to increases in product innovation and design. Rogers and Greenhalgh (2006) consider UK financial service sector firms (1996-2000), finding that while larger firms account for more trademarks, the trademark to employment ratio is higher for small firms. They also investigate whether stock market listed firms and more diversified firms trademark more, but find no role for either factor.

An interesting study of all European trademark applications at OHIM during the 1996-2004 period by von Graevenitz (2007) looks at the determinants of the rate at which these are opposed by other firms, using a structural model of litigation and settlement. He finds that more valuable trademarks are more likely to succeed, and that developing a reputation for toughness encourages settlement of the opposition before adjudication, lowering costs. His paper also contains considerable statistical information on the characteristics of these trademarks.

4.2. Copyright

Empirical analysis of the value of copyright is difficult since there is (currently) no legal requirement to register creative work.[23] Nevertheless, there are a few studies that generate some information on the economic role of copyright. Country-level studies, although not directly relevant here, do provide some background. A study on the US during the period when copyright had to be registered (and renewed), concluded that around 80 per cent of copyright had little economic value (see Landes and Posner, 2003, who looked at the 1910-1991 period). This result is consistent with the generally very skew distribution of value for a wide range of innovation measures (Scherer 1998).

Baker and Cunningham (2009) looks at aggregate quarterly copyright registration in the US and Canada during the 1986-2005 period and how it responded to changes in the copyright term extensions and other changes to the law, finding a small positive impact of term extension. However, there are some problems associated with the lack of a requirement for registration unless legal enforcement is required and the timing of the registration.

Png and Wang (2009) look at the impact of copyright extensions on the production of movies in 23 OECD countries, and found no statistically robust evidence that copyright term extension was associated with higher movie production. This result is not surprising, since the net present value of such a 20-year increase is very low (if a standard discount rate is used). They also looked at the impact of European revisions to copyright law in response to the EU's Rental Directive (which arguably strengthened the rights of movie producers to receive returns from rentals) and found no effect.

Firm-level studies on copyright are more difficult. One approach is to use data on court actions. Baker and Cunningham (2006) look at the effect of US federal court decisions that broadened copyright on the market value of firms. They find that a new copyright statute can raise return on equity by between 0.4 per cent and 2.1 per cent; while a high court decision can raise returns by 0.1 per cent to 1.1 per cent. In a similar type of study, Mazeh and Rogers (2006) find that plaintiffs in copyright disputes have higher market values than a peer group of similar firms. Overall, however, the empirical evidence on the value of copyright, especially at the firm-level, is sparse.

It is probably worth emphasizing that for copyright as for other formal IP protection methods, there is a great difference between its role as an *ex ante* incentive and as an *ex post* profit generator. It is probably safe to say that there is very little evidence that the incentive to produce creative works is impacted by term extensions of the kind we have seen recently, but that does not mean that the firms holding the very small share of

[23] Historically some countries, including the US, required copyright to be registered, but under TRIPs countries cannot now make such a requirement.

copyrighted works that have a long lifetime (think Disney Films) will not experience market value effects in response to extensions of the term.

4.3. Multiple and overlapping IP use

Firms typically have more than one invention and, furthermore, tend to bundle different IP protection tools (e.g. Levin *et al.*, 1987). In fact, most of the surveys that ask firms about their preferences for various IP protection methods find that their answers are correlated, implying that firms have a general taste for IP which manifests itself as a preference for all the different methods. This view is supported by the interview evidence in Graham and Somaya (2006).

In much empirical work it is impossible to determine what exactly is protected by which IP protection instrument. Different IP protection tools may be used at different stages of the innovative process. For example, secrecy may be applied in early stages of the innovative process and patents may be used to protect the invention when it is going to be commercialized. After the invention has entered the market, however, patents and secrecy are mutually exclusive for a particular invention because of the patents' disclosure requirement. Theoretical models tend to focus on one invention 'level' and tackle the question which IP tool is most suitable for this particular invention. However, empirical research at the firm level cannot tell, whether patents and secrecy are used for one or more particular inventions, but focus on the use of patents and secrecy by firms in general. This issue presents a challenge for empirical analysis. Indeed, data surveys that are commonly used for this type of analysis (like the Community Innovation Survey) are unable to distinguish the different stages of the innovation process, hence where patents vs. secrecy might be differentially important.

Graham and Somaya (2006) argue that IP protection methods are often complements rather than substitutes, and offer as an example computer software, where copyright, trademarks, and patents are often used together. The difficulty in examining the use of these methods empirically is that copyright is often unregistered, and trademark data can be rather noisy. The authors solve this problem by looking at changes in litigation rates for copyright and trademarks within firms over time. They are able to show that after they control for firm size, age, R&D, income, managerial attention to IP, firm IP resources, and firm fixed effects, the residuals in the copyright and trademark litigation rates are correlated, suggesting complementary use of the two above and beyond the overall IP profile of the firm.

5. Conclusions

The review of theoretical models presented here highlighted a wide range of factors that could be important in the decision to use patents or secrecy. Most of the theoretical work concentrates on the choice of patents vs. secrecy, even though trademarks and copyright are likely to be the more widely used IP rights. The theoretical models, as is to be expected, make various assumptions that isolate and analyze specific factors: there is no single encompassing model. This means that the implications of the theoretical analysis can be overlapping and sometimes contradictory. We have attempted to classify the diverse factors that influence the choice of patents vs. secrecy, including whether it is a process or product innovation, the intensity of competition between innovators, the expected value of innovation and the costs of the patent system. An important implication from this analysis is that different industries are likely to have different sets of influencing factors, hence different propensities to use patents (or other forms of IP). This, in fact, is one of the major results from empirical analysis. For example, patents play a key role in the pharmaceutical and chemical industry for both product and process inventions, but a lesser role in some other sectors.[24] On the other hand, the use and importance of patents has been changing and growing in some ICT sectors, largely for strategic reasons.

The theoretical literature also indicates that patents can serve a range of functions, in addition to the standard 'reward' argument. Patents can be used to obtain licensing revenue, as bargaining chips in negotiations and as a defensive strategy to prevent lawsuits. The decisions of large firms may be particularly guided by such 'strategic' issues. While small firms also need to be strategic, they may also use patents to demonstrate technological ability and capitalize intangible assets. Smaller firms may also be more financially constrained and hence more sensitive to the costs of the patent system.

The empirical literature discussed above attempts to understand the factors that induce a firm to choose secrecy to protect its IP rather than patenting it. Surveys show that some industries seem to systematically prefer secrecy to patenting. For example, in bio-tech patenting is a vital part of corporate strategy, whereas some studies find firms in other sectors, notably software, essentially avoid the patent system altogether. Equally, patents play a leading role in the pharmaceutical and chemical industry. From our review of the theoretical literature, this result should come as no surprise: theory suggests that the nature of innovation (product vs. process and discrete vs. complex) along with the degree of competition among innovators and in the product market are the key factors that shape a firm's propensity to use secrecy rather than patents. Since these factors also vary across time, and across countries, we should also expect to see the propensity to patent varying. Even in patent intensive industries, secrecy can be important in protecting process innovations. This apparent inconsistency is due to the fact that many firms have a bundle of inventions and innovations, and their different characteristics may call for different IP strategies.

[24] Using financial market data for US firms, Bessen and Meurer (2008) find that patents provide a net benefit only in chemicals and pharmaceuticals.

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