DISCUSSION PAPER SERIES

DP16045

The functions of patents in our societies: innovation, markets, and new firms

Alfonso Gambardella

ORGANIZATIONAL ECONOMICS

ISSN 0265-8003

The functions of patents in our societies: innovation, markets, and new firms

Alfonso Gambardella

Discussion Paper DP16045
Published 16 April 2021
Submitted 10 April 2021

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

The functions of patents in our societies: innovation, markets, and new firms

Abstract

This article provides a review of the role and functions of patents in society using data and evidence from the economic and management literature. While patents provide private protection to appropriate the returns from inventions, they also encourage their diffusion – in particular, they provide signals about the value of new firms, disclose information about the invention, and encourage the exchange of inventions and ideas in markets for technology. In order to better understand this trade-off, Patent Agencies and stakeholders should invest to a greater extent in data collections or in creating the conditions for research designs and experiments that nail down causal effects and mechanisms. Most available data are not created with these identification strategies in mind, which limits the questions that scholars can ask. Systematic studies that identify different effects of patents can provide the basis for rigorous evidence-based management and policy about patents.

JEL Classification: O31, O32, O33, O34

Keywords: patents, IPR, Innovation, start-ups, markets for technology, general-purpose technologies

Alfonso Gambardella - alfonso.gambardella@unibocconi.it
Bocconi University and CEPR

Acknowledgements
This study is the output of a research collaboration between the ICRIOS Research Center of Bocconi University, Milan, and 4iP Council. The author also acknowledges financial support for the collection of the InnoS&T data of the European Commission [Contract FP7-SSH-2007-1] and the Italian Ministry of Education, University, and Research [Project CUP B41J12000160008.] Content and errors are solely the responsibility of the author

1. INTRODUCTION

This article discusses some aspects of the impact and implications of patents for firms and our societies at large, drawing on data, evidence and insights from the economic and management literature. The article does not aim at covering all relevant topics about patents. The subject of patents and the literature are so vast that it will be impossible to cover all these topics in the space of one article. The article is a selection of topics and problems that the author believes are worth the attention of readers, with no claim to exhaust all topics and issues worthy of attention.

Some points discussed in this article are relevant for other intellectual property rights (IPR), such as trademarks, designs, copyright, geographical indications, and plant variety rights. However, this article focuses on patents, and because these other IPR are different from patents, these extensions should be made with caution.

A focal theme of this article is the dual role of patents. By this we mean the distinction between the value of patent rights to the individual owners and the broader value of patents in our societies, or more generally between the private and social role of patents.

Patents are economic assets. Like any other economic assets, the value for their owners is equal to the sum of the discounted stream of profits generated by the asset. Since patents provide temporary exclusive exploitation rights, the value of patent rights is the discounted sum of profits generated by the use of the invention under temporary monopolistic conditions.

The broader value of patents in our societies depends, instead, on the fact that they can signal the quality of inventors or organizations, disclose information about inventions that generates spillovers or avoid duplications in research efforts, and encourage efficient markets for the exchange of technology disembodied from physical products.

The classical perspective on patents highlights that they privatize inventions. The broader perspective of this article highlights that they also help the diffusion of knowledge and perform other valuable functions in our societies. This perspective raises natural points of discussion – in particular, how important are these different roles and functions of patents? How much do policies that target one goal also affect the others? To what extent can policies optimize trade-offs among these goals? As this articles documents, quite a few studies have begun to examine these dual roles of patents. However, we need more studies and more importantly we need data that enable us to understand better how patents affect these goals, and therefore how patents affect innovation, and then economic efficiency and growth. This calls for the collaboration of Patent Agencies and other institutions or stakeholders that can raise relevant questions and encourage data collections, research designs and experiments to nail down causal effects and mechanisms. This will provide the basis for rigorous evidence-based management and policies about patents.

Section 2 focuses on the value of patent rights and provides some estimate of it. Section 3 focuses on the broader value of patents. It discusses the role of patents as signals of value, in disclosing information about inventions, in encouraging markets for technology, and more generally in favoring the diffusion of innovation. Section 4 concludes by discussing policy implications and by proposing new analyses and data collections to better study the role of patents in our societies and to test and implement policies.

2. THE VALUE OF PATENT RIGHTS

2.1 Distribution of the value of patent rights

Estimating the value of patent rights is not easy. Gambardella et al. (2008) provide one of the first attempts to measure this value using systematic data on European Patent Office (EPO) patents. They use data from the PatVal-EU survey (Giuri et al., 2007), which collects data on 9107 patents granted by the European Patent Office, with priority dates 1993-1997, whose inventors are located in France, Germany, Italy, Netherlands, Spain, and the UK. The project collected the data by surveying the patent inventors. It selected a representative sample of the patents granted by the EPO to inventors in these six countries, with a slight overrepresentation of patents with a larger number of citations. Giuri et al. (2007) provides details about the data collection and the sample.

Gambardella et al. (2008) employ data on the 8217 PatVal patents whose inventors answered the following question: *if the owner of this patent sold it on the day of grant, what would be the minimum price at which they will sell the patent to a close competitor?* The inventors could pick one of the following 10 intervals from less than 30 thousand (30K) euros to more than 300 million (300M) euros: < 30K; 30K-100K; 100K-300K; 300K-1M; 1M-3M; 3M-10M; 10M-30M; 30M-100M; 100M-300M; > 300M. Since we expect patent values to be skewed, these classes mirror a logarithmic distribution because the ratio, instead of the difference, of the two boundaries is roughly the same.

This question assumes that the answer is an estimate of the discounted sum of future profits that the owner of the patent gives up by releasing the patent right. It is then an estimate of the value of the patent right rather than the value of invention. One problem with inventor assessments is that inventors may overestimate the value of their own patents. However, as a robustness check, the paper uses a subsample of patents to compare the responses of inventors with the managers responsible for development of the invention who ought to be less emotionally attached to it. The estimates of inventors and managers are not very different.

This measure clearly has limitations, the most important one being that it is a subjective estimate, albeit made by individuals with experience and expertise about each specific patent. Stock market responses to news about patents, such as Kogan et al. (2017) that we discuss in the next section, are also evaluations of patent assets based on predictions. This measure relies on the fact that financial markets make credible predictions. However, financial markets only cover publicly traded companies. Moreover, unlike the US, Europe does not have one financial market, and each national financial market is not equally representative of all firms in the different countries.

Our measure covers instead a larger set of patents, possibly representative of the population. Moreover, the inventor responsible for the patent is one of the most knowledgeable people about the patent, and, as noted, the predictions of inventors do not differ much from those of the managers. Other measures, such as the use of renewal fees (e.g. Schankerman, 1998), only provide a lower bound, and since these fees are smaller than the value of many patents, this lower bound is unlikely to be reliable.

With these caveats in mind, Gambardella et al. (2008) find that the distribution of the value of patent rights is very skewed. They estimate a mean of about 3 million euros, a median of about 400 thousand euros, and a mode of about 6 thousand euros (Gambardella et al., 2008, Table 8). Apart from the slight overrepresentation of more valuable patents in the sample, EPO patents are likely to be more valuable than patents applied only to the national patent offices. Thus, these figures are likely to imply a slight overrepresentation towards higher values. The paper shows that these estimates are correlated with several indirect indicators commonly used as proxies for patent value, such as forward and backward citations, number of claims, and other such measures.

Taking into account potential sample selection or vagaries in inventor responses, a fair claim is that these estimates show that the value of patent rights is highly skewed. This suggests that, compared to the mean, the median is more likely to be representative of the value of patent rights of the typical patents.

The InnoS&T survey is a follow-up of PatVal-EU. It covers 23,044 representative EU patent applications with priority dates 2003-2005 by inventors located in 20 European countries, Israel, Japan, and the US. InnoS&T also surveyed the inventors and tried to make the final sample as representative as possible of the universe of EU patents in these countries. Torrisi et al. (2016) provides a comprehensive description of InnoS&T and its data.

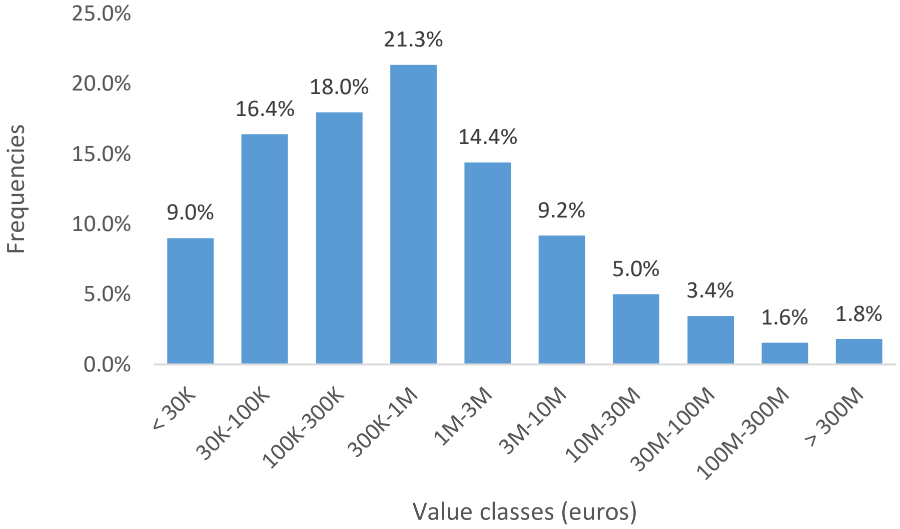
InnoS&T asked the same question about the value of patent rights using the same 10 classes of PatVal-EU, with one difference. InnoS&T recognizes that patents can be technically connected, and more patents can cover different inventions that are part of the same broad invention. Therefore, for each patent InnoS&T asks how many patents are technically connected to it. Note that this is not the patent family, which is the term used to mean the number of jurisdictions that granted protection to a given invention. It is a genuine measure of the number of technically connected patents as perceived by the respondent. The survey finds that nearly 60% of patents are stand-alone and the rest is connected to one or more patents. The InnoS&T question asks for the value of the whole set of connected patents. This is a more precise representation of value because it measures the value of patent rights for the entire set of patents that cover a core invention.

Figure 1 reports the distribution of these values using the 15,311 patents for which the project obtained answers to the question about value. This distribution is skewed and very similar to the distribution in Gambardella et al. (2008). PatVal-EU collected data for patents with priority years 1993-1997 in 2005, while InnoS&T collected data for patents with priority years 2003-2005 in 2010. The similarity of the two distribution suggests that skewness is a robust pattern of the value of patent rights.

Using the InnoS&T data, we estimated the mean, median and mode of the distribution, following the same procedure employed in Gambardella et al. (2008) to make the comparison more homogeneous. We report these estimates in Table 1 along with the estimates of PatVal-EU in Gambardella et al. (2008). The table explains the methodology we used. InnoS&T estimated that the expected value of patent rights is about 10 million euros, the estimated median is about 591 thousand euros, and the mode is 2 thousand euros. The estimated mean and median are higher than PatVal-EU because InnoS&T asks for the value of the whole set of connected patents.

Table 1 also reports mean, median and mode of the value of patent rights divided by the number of patents in the set. This provides a more comparable measure with PatVal-EU. In this case, estimated mean, median and mode are respectively 4.6 million, 338 thousand and 2 thousand. These values are closer to PatVal-EU.

Figure 1: The value of patent rights



Based on 15,311 EU patent applications from the InnoS&T survey with available answers on the following question: "if the owner of this patent sold it on the day of grant, what would be the minimum price at which they will sell all technically related patents for this innovation?" Inventors indicates one of the 10 value classes. InnoS&T patents have priority dates 2003-2005, and inventors are located in 20 European countries, Israel, Japan and the US. See Torrisi et al. (2016) for details about the survey.

Table 1: Estimated distribution of value of patent rights

	InnoS&T		**PatVal-EU**
Parameters (000euros)	***Value of portfolio (15311 obs.)***	***Average value of patent in portfolio (11760 obs.)***	***Single patent (8217 obs.)***
Mean	10473.4	4598.03	3138.6
Median	591.2	338.34	397.4
Mode	1.9	1.8	6.4

Portfolio = set of technically connected patents. Assumes log-normal distribution of value and retrieves mean, median and mode using mean and standard deviation of the log of the mid-point of value classes as parameters of the associated normal distribution. See Table 8 of Gambardella et al. (2008) for details. Values adjusted by lower proportion of German patent values because German Inventor's Act provides German inventors with an anchor evaluation.

While we should be cautious about these figures, it is interesting that we have similar evidence on the same question from two waves of a large-scale survey a few years apart. Also, while we still need to be cautious about these predictions, they suggest that the returns produced by patented inventions are not trivial. Moreover, as noted, the skewness of the distribution is a robust and credible result, which implies that the predicted returns are likely to vary considerably across patented inventions. In particular, some patented inventions in the right tail of the distribution produce very high returns.

We also looked at differences across the six macro-industries industries defined by Torrisi et al. (2016): Electrical Engineering; Instruments; Chemicals; Process Engineering; Mechanical Engineering; Consumption and Construction. We find a similar skewed distribution as in Figure 1 for all these industries. The only relevant difference is in Chemicals and Pharmaceuticals where we find a fatter right tail. On further inspection, this fatter right tail is largely concentrated in the pharmaceutical industry, where, as expected, we find the largest share of patents worth more than a few hundred million euros.

Table 2 reports the value of patent portfolios equivalent to Table 1 by these macro-industries. As the table shows, mean, median and mode of the log-normal distribution are fairly similar, suggesting that the aggregate patterns do not underlie important industry differences. Again, the only difference is Chemicals, and in particular Pharmaceuticals, where we find a higher mean and median, but a similar mode. This suggests that in these industries the skewness of the distribution of values is higher, and there are quite valuable patents in the right tail.

Table 2: Estimated distribution of value of patent rights, by macro-industries

Parameters (000euros)	***Electrical Engineering (3663 obs.)***	***Instruments (2501 obs.)***	***Chemicals (3004 obs.) (*)***	***Process Engineering (2110 obs.)***	***Mechanical Engineering (2944 obs.)***	***Consumption & Construction (1089 obs.)***
Mean	9163.0	11263.9	28448.2 (37205.9)	7878.8	4446.8	5888.5
Median	477.1	662.9	1179.3 (1299.2)	543.8	409.5	441.5
Mode	1.3	2.3	2.0 (1.6)	2.6	3.5	2.5

InnoS&T values of portfolio by industries computed as in Table 1. See Torrisi et al. (2016) for definition of macro-industries. (*) Values of Biotechnology and Pharmaceuticals & Cosmetics in parenthesis (804 obs.)

2.2 Estimated returns of patent rights

To provide some perspective about the estimates in the previous section, consider the estimated median value of patent rights in Table 1, 591 thousand euros. Gambardella et al. (2017, Table 1) reports that the median man-months invested in the InnoS&T sets of technically connected patents is equal to 8.5. The order of magnitude of 8.5 man-months invested in R&D in Europe in 2003-2005, the priority dates of our patents, is about 200 thousand euros. The median value of patent rights is then about three times the labor cost for the median patent. Again, these figures have to be taken as tentative and with caution. However, they suggest that even "ordinary" patented inventions, such as the patents around the median, and not just the ones at the very high-end, yield important private returns.

Back of the envelope calculations suggest high returns at the aggregate level as well. In 2003-2005, the business sector in Europe spent annually about 125 billion euros in R&D. We focus on the business sector since the expenditures of the higher-education and government sectors are much less likely to produce patents. In the same period there were about 60 thousand annual EU patent applications. As we will see in Table 5 below, firms cover about 90% of the patent applications, and thus in 2003-2005 firms produced about 54 thousand patent applications. If we employ the estimated mean of the value of patent right per individual patent in Table 1, which is 4.6 million, we obtain a total value of patent rights of about 250 billion. This 100% return on patent rights is not far from the 60% patent premium with respect to R&D estimated by Arora et al. (2008) using data for US manufacturing firms.

In Section 4 we discuss how we can dig into these issues by collecting more precise data and by conducting more rigorous and precise analyses. However, the comparison with an independent study such as Arora et al. (2008) suggests that these figures pin down the orders of magnitude. If so, the average return to patent rights is way above the returns from ordinary financial securities. While this hides significant heterogeneity across individual inventions, it is a sizable average return.

We can also compare these figures with Kogan et al. (2017) who conduct a rigorous study of the effects of patenting on the financial returns of companies following news about patents. The study is comprehensive in that it covers patents by US firms between 1926-2010. They find a much higher median value of patent rights, 3.2 million in 1982 US dollars. Kogan et al. (2017) compare this figure with the PatVal-EU figures and recognize this difference. They argue that their sample is only composed of public firms, and that financial evaluations may take into account the value of future patents spring from the focal patent. Also, because their estimates depend on variations in stock market returns, they may depend on the value of invention, and not just the value of patent rights.

Recently, text analysis and natural processing language offer new opportunities to estimate patent quality, as a proxy of patent value (e.g. Higham et al., 2020; Hsu et al., 2020). These are interesting approaches, and we should look forward to their developments. However, even with sophisticated techniques, the skewed distribution of patent values casts serious doubt on our ability to predict the value of individual patents *ex-ante*, that is, before or in absence of any clear transaction of the patent in the market. Since only a small percentage of patents is traded, and they are clearly a selected sample, this makes it particularly hard to obtain *ex-ante* estimates. These techniques will of course be more effective in estimating the average value of groups of patents, for instance patent portfolios.

More generally, there are at least two reasons why even with sophisticated techniques based on natural processing language it will be difficult to make *ex-ante* assessments of the value of individual or small groups of patents.

First, the *ex-post* value of patents has a transaction-specific component. Since most of these transactions are bilateral, the equilibrium price is going to be anywhere within the reservation prices of the buyer and seller. The exact equilibrium price will depend on the bargaining power of the parties, which in turn depends on idiosyncratic conditions such as the competition that they face in buying or selling the patent, the specific goals and context in which they will be using the patents, the characteristics of the specific buyers and sellers, and other such elements.

Second, as showed by Choudhury et al. (2020), patent lawyers, or anyone who writes the patents, are likely to change their language, sometimes strategically, to establish the novelty of the patent or to affect the strength of protection. This makes it harder to identify patent quality based on a stable body of language.

All this suggests that a fruitful line of inquiry would be to test specific contexts and conditions to assess the value of patents under specific circumstances of interests to policy-makers or firms and other agents – such as the value of patents of a particular firm or set of firms (e.g. small firms) for evaluation (financing or acquisition), or the value of patents associated to a particular technology or market. To do so, the best approach would be to collect evidence by designing and running lab, field, or survey-based experiments based on randomized control trials, or by using data from patent statistics and surveys together with natural or quasi-natural shocks to uncover causal relations and mechanisms. We will take up this point again in Section 4.

However, we can still make some general statements using the aggregate evidence discussed in this section. In particular, the comparison with Kogan et al. (2017) suggests that the estimated parameters of the PatVal-EU and InnoS&T distributions are probably not overestimates. If anything, they may underestimate the value of patent rights. Simply put, patented inventions appear to be investments with important private economic returns.

2.3 A closer look at the returns to patent rights

The estimated returns to patent rights discussed in the previous section raise some relevant question. First, if the returns are so high, why do we not see many companies making these investments? A natural answer is that there are frictions that prevent open entry into the innovation activity. Firms may have different propensity towards risk, and probably more importantly, the ability to make successful investments in patented inventions is not widely spread, especially since the productivity of R&D seem to have diminished (Bloom et al., 2020). We may be dealing with a scarce resource that can only be nurtured by appropriate policies that support education and, more generally, that supports the skills to produce innovations. An even more important answer to this question is that, by definition, patent rights produce high returns because they attribute monopolistic rights to use of the invention.

This raises a second important question. Are these high private returns valuable for society as well, or are they only valuable for private holders of patent privileges? This question is hard to answer, and we can certainly not answer it in this article. However, we can provide elements for this debate. In particular, in the next section we argue that patents have broad values for society because they provide information about firms and technologies, increasing the transparency of markets, and they help the creation of markets for technology, enhancing their diffusion.

Even within the context of the protection of patent rights, they can produce more value than the value accruing to the owners of patents. A recent study by Kline et al. (2019) uses the estimated returns by Kogan et al. (2017) to show that workers capture on average 30% of the value of the patent rights in the form of higher wages. This share rises to 60% for workers employed by the company since the year of patent application. This raises another issue because the paper also shows that men and workers in the top 50% of the earning distributions are more likely to capture these rents. Thus, firms do not capture all the surplus generated by patented inventions, and they raise inequality among workers.

This suggests that the culprit for potential inequality across firms or individuals is only in part the notion or the rationale of patent rights. Kline et al. (2019) show that the rents accruing to more senior and reputed workers stem from the fact that they are costlier to replace, and thus companies pay them rents. Policies that support wider education and thus a wider supply of qualified workers may then raise the surplus that accrues to company managers and shareholders because there will be a more competitive supply of talented workers. However, qualified workers may create their own firms. A wider set of people could then earn rents from patented inventions through their own firms. We highlight this point in the next section when we discuss the value of patented inventions for new firms.

Gambardella et al. (2017) provide additional evidence on the fact that the returns to patented inventions need to be understood more deeply. They use the InnoS&T survey-based measure of the value of patent portfolios. Technically connected patents may reflect, on the one hand, more complex technologies or technologies with different potential applications, or, on the other hand, an increase in the strength of protection irrespective of an increase in the complexity of technology or the breadth of potential applications (Ziedonis, 2004).

Using the InnoS&T data, Gambardella et al. (2017) show that twice as many man-months invested in a project that produces a given number of technically connected patents (that is, a 100% increase in man-months) raises the value of the portfolio by 46%. Given the same investment in man-months, they find that twice as many patents make the value of the portfolio nearly twice as big (100% increase). Thus, increases in the number of patents affect value in an important way.

Another way to think about these results is that twice as many man-months increase the average value of patents in the portfolio by 46%, while an increase in the number of patents leaves this average value unaltered. Thus, the value of the portfolio is proportional to the number of patents. The proportionality factor is then a crucial determinant of the value of both individual patents and the whole portfolio.

Gambardella et al. (2017) also examine potential heterogeneous effects. They find heterogeneity in the returns to the number of patents in the portfolio. For example, they find higher returns to the size of portfolio in pharmaceutical and biotech, which are likely to reflect more important and complex inventions than in other industries, where we are more likely to observe isolated inventions. The returns to the number of inventions are also higher when feedback from customers are important, which suggests adaptation of inventions to differentiated needs around a core invention.

The returns to larger portfolios are higher when blocking rivals is an important motivation for patenting, suggesting that larger portfolios raise the value of protection. Thus, overall, the study finds that the value of larger portfolio depends on both protection and genuinely more complex inventions.

3. THE BROADER VALUE OF PATENTS IN SOCIETY

3.1 Patented inventions in different firms and industries

EUIPO (2019a) reports that patent applications by EU applicants have increased steadily from slightly less than 60,000 in 2004 to more than 70,000 in 2018. (See also WIPO, *various years*.) This study also provides an extensive account of the impact of patents in European economies. It shows that, in 2010-2014, out of 615 NACE 4-digit industries in Europe, 467 filed at least one patent application and 148 are patent-intensive. The study defines patent-intensive industries as the industries with a ratio of patents filed per 1,000 employees higher than the weighted average of the 467 industries, using the share of industry employment as weights. This weighted average is 0.937.

In 2014-2016, patent-intensive industries show higher productivity than average because they cover 10.9% of total EU employment and 16.1% of the European GDP. EUIPO (2019a) also reports that in Europe patent-intensive industries pay on average 72% higher wages than non-patent intensive industries.

This study provides the interesting opportunity to compare patent-intensive and trademark-intensive industries. Patent-intensity is more likely to be associated with technical inventions, while trademark-intensity is more likely to be associated with the commercialization of goods and services. According to EUIPO (2019a), in 2010-2014, out of the 615 NACE four-digit industries, 508 filed at least one trademark, and 280 are trademark-intensive, with trademark-intensity defined as patent-intensity replacing trademarks for patents. The weighted average of trademarks is 4.726.

Trademark-intensive industries are more productive than average, covering 21.7% of total EU employment and 37.3% of total EU GDP. In Europe they pay 48% higher wages than non-trademark intensive industries.

These figures indicate that trademark-intensive industries are less concentrated than patent-intensive industries (280 vs 148), and on average industries produce more trademarks than patents per 1,000 employees (4.726 vs 0.937). Trademark-intensive industries cover a higher share of employment and GDP than patent-intensive industries (21.7% vs 10.9; 37.3% vs 16.1%), and show higher productivity (16.1/10.9 = 1.48 vs 37.3/21.7 = 1.72). However, patent-intensive industries pay a higher wage premium (72% vs 48%).

These figures mirror a known but relevant phenomenon. Relatively, fewer industries specialize in the production of patented inventions than industries that specialize in the production of goods and services. However, patent-intensive industries generate fewer rents than trademark-intensive industries as implied by the fact that patent-intensive industries show higher wages and lower revenues per employee. The higher wages suggest that there is relative scarcity of labor employable in patent-intensive industries. This is a natural implication of the fact that it is more costly to raise the supply of labor in these industries, since it requires greater personal investments in human capital. In addition, there may be constraints in the investments in educational infrastructures. The lower revenue per employee is consistent either with a lower relative demand for the outputs of patent-intensive compared to trademark-intensive industries, or with greater competition in patent-intensive industries.

Industries that produce technological innovations need profits to invest in R&D, but rents accrue to a greater extent to the industries that commercialize innovations. This calls for investments in education that increase the supply of qualified labor, or interventions, such as patent protection, that raise the rents of innovators. Lower rents also imply that patent-intensive industries attract relatively less capital than trademark-intensive industries. By raising rents, these industries may then attract more capital, increasing the number and scale of innovation activities in our economies.

However, this raises the question why we ought to introduce these distortions to raise technological innovations. Since innovations are engines of growth, too little demand or supply of innovations suggest that individuals discount the future too much. If we believe that we care too much about present compared to future outcomes, policies ought to raise the supply of qualified labor or the rents of patent-intensive industries.

Of course, these aggregate figures reflect average effects, and there is clearly heterogeneity across industries and firms. For example, some of the technology giants today are building on their technological capabilities to earn considerable rents, and they reinvest these rents in R&D and innovation. However, many firms with technological capabilities may not earn enough rents to invest in R&D and innovation, while this seems to be a less serious concern for firms that profit from products covered by trademarks. Moreover, industries and firms that bet in technology attract less capital. As we will see, constraints in the ability to obtain rents to fund R&D and innovation are particularly relevant for smaller innovative firms. Patents are one of the means that can help these industries and firms to restore these opportunities.

Table 3 reports the number and shares of patent-intensive and other-IPR intensive industries in the EUIPO (2019a) study. The table distinguishes between patents and all the other IPR (trademarks, designs, copyright, geographical indications, and plant variety rights). A reasonable distinction is that patents cover technological inventions, while all the other IPR cover activities closer to commercialization. Even copyrights, which are closer to pure creativity, are typically associated with products close to commercialization (e.g. books, music, software programs). Patented inventions require instead further actions and investments before generating products, services or other activities that produce economic value. However, trademarks cover the bulk of the other IPR, and the qualitative message that arises from the table does not change if we eliminate some of the IPR in the non-patent group.

Table 3: Share of patent-intensive and other-IPR intensive industries, 2010-2014

		Patent-intensive industries		
Other-IPR intensive industries		*No*	*Yes*	**Total**
	No	262 (42.6%)	17 (2.8%)	**279 (45.4%)**
	Yes	205 (33.3%)	131 (21.3%)	**336 (64.6%)**
	Total	**467 (75.9%)**	**148 (24.1%)**	**615 (100%)**

Source: Calculations from Table 20, p.68, EUIPO (2019b)

Table 3 shows that only 24.1% of the NACE 4-digit industries in Europe are patent-intensive, while 64.6% of these industries are intensive in one or more of the relevant IPR for commercialization. This provides further evidence of the greater spread of capabilities in the production and commercialization of goods and services, compared to technological innovations. The majority of industries intensive in non-patent IPR are not patent-intensive (33.3% vs 21.3%).

Thus, many industries specialized in the production of goods and services do not have the capabilities to produce technological innovations. Since the industries that are neither patent-intensive nor intensive in the other IPR are, nonetheless, producing goods and services, only 131 of the 598 (467+131) industries that produce goods and services are also patent-intensive – that is, they have internal capabilities to produce technological innovations. Only 17 patent-intensive industries specialize in the production of technological innovations. Our economies then show a sizable potential demand for technological innovations by industries that operate in the markets of goods and services but do not have the capability to produce technological innovations.

In order to understand better which firms and industries may be penalized by this asymmetry in profit rates to support R&D and innovation, an earlier study focuses on IPR at the firm level (OHIM, 2015). Using data on 2.3 million firms in 12 European member States, this study first shows that 10.4% of large firms (> 250 employees) own patents vis-à-vis only 0.8% of SME (250 employees or less). Thus, patenting is far more common among large firms than SME. A recent EUIPO (2021) study provides similar results using 2007-2019 data on a representative sample of 127,199 firms in all 28 European States. In this sample, 0.9% of SME own patents vs 17.8% of large firms.

The InnoS&T survey (Torrisi et al., 2016) confirms this picture from the point of view of the share of patents by firm size. This survey collects data from interviews with the inventors of EU patent applications in 20 European countries, Israel, Japan, and the US, with priority dates 2003-2005. The survey received 23,044 responses (18% response rate) and tried as much as possible to build a representative sample of EU patent applications (See Torrisi et al., 2016 for details.). As Table 4 shows, large firms cover the bulk of EU patent applications (more than two-thirds), with very large firms (more than 5,000 employees) covering more than 50%. SME cover slightly more than one-fifth, and universities and other research labs cover shares in the range of one-digit figures. This sets the stage of our discussion. Firms account for the vast majority of patents, and most patents belong to large or very large firms.

Table 4: Share of EU patent applications by type of applicants

Type of applicant	Shares
SME (≤ 250 employees)	22.9%
Large Firms (> 250 employees) ***(Firms with ≥ 5,000 employees)***	68.8% (52.1%)
Government Research Organizations	2.6%
Universities and Higher Education	3.9%
Others (Hospital, Foundations, Private Organizations, Others)	1.8%
Total	100.0%

Based on 20,325 EU patent applications from the InnoS&T survey with available information on ultimate parent applicant.

The OHIM (2015) and EUIPO (2021) studies also run econometric analyses. The OHIM (2015) study employs a representative sample of 130,555 European firms from 12 Member States during 2002-2010. The EUIPO (2021) study uses the more representative and updated sample of 127,199 firms during 2007-2019 in all 28 European States. The econometric analyses of these two studies only provide correlations, and not causal relations. In particular, it is hard to conclude that the effects discussed below depend on property rights or on the fact that, for example, patents proxy for innovation capabilities, and trademarks or designs proxy for product commercialization capabilities. Nonetheless, the associations are informative, especially about differences between small and large firms.[1]

The OHIM analysis shows that ownership of IPR is associated with a higher labor productivity of SME (revenue per employee) by 17% if they only own patents, 41% if they own trademarks and designs together with patents, and 22% if they own patents and one of the other two IPR. Conversely, ownership of patents is not associated with higher labor productivity of large firms, whether they only own patents or patents together with trademarks or designs. Only large firms that own only trademarks are associated with a higher labor productivity of 9%.

The more recent EUIPO (2021) study provides consistent results. The labor productivity of SME that only own patents is 50% higher than SME that do not own any IPR. This differences raises to 98% if they also own trademarks and designs, and it is in between if they only own one of these two other IPR in addition to patents. EUIPO (2021) finds that large firms also exhibit a positive association between IPR and labor productivity. The effect ranges from 18% if they only own patents to 28% if they also own trademarks and designs, with values in between if they own only one of these two other IPR in addition to patents.

The EUIPO (2021) provides higher effects associated with IPR for both small and large firms. However, the relative effect does not change. Small firms are associated with stronger effects of the IPR measures on productivity. A natural interpretation is that large firms own sizable research, production and commercialization assets that have two potential effects, according to whether we interpret IPR as proxies for innovations (patents) or new products (trademarks or designs), or as measures of property rights.

On the one hand, the sizable assets of large firms raise their labor productivity. As a matter of fact, both OIHM (2015) and EUIPO (2021) report a positive association between large firms and labor productivity. If we interpret IPR as proxies for innovations or new products, at the margin the contribution of innovations or new products is relatively smaller for large vs small firms because their assets already account for their higher productivity. Smaller firms, which do not own these other assets, then benefit relatively more from innovations or new products.

On the other hand, these assets already provide some degree of protection for innovations or new products, making large firms naturally more protected than small firms. Merges and Nelson (1990) argue that IPR provide a smaller marginal contribution to protection given that large firms already enjoy protection from their complementary assets. (See also Arora and Ceccagnoli, 2006.) This would explain why SME enjoy systematically higher associations between IPR and labor

---

[1] In what follows we discuss estimated percentage changes in labor productivity from the econometric analyses in Table 16, p.59, of OHIM (2015) and Table 12, p.50, of EUIPO (2021). Since the dependent variable of these regressions are in logs, we obtain the percentages below by subtracting 1 to the exponential of the estimated coefficient.

productivity compared to large firms. In this case, protection matters more from them since they do not have other means of protection.

Also, both studies show a higher difference in the labor productivity of SME vis-à-vis large firms when they only own patents vis-à-vis owning no IPR. This suggests that, for SME, owning only patents is already associated to sizable changes in productivity, and it is consistent with the interpretation that they draw more value from patents because they can sell or license technology, or as signals of reputation. The opportunity of selling or licensing technology, or the role of patents as signals of reputation, are less important for large firms.

3.2 Uses of patents

The discussion in the previous sections suggests that we need to understand better the uses of patents. We distinguish among five main uses of patents:

- Internal commercial use
- Licensing or sale of patents
- Creation of start-up
- Strategic use
- Sleeping patents

Internal commercial use indicates that firms embody patented inventions in products or services that they sell. Licensing provides other parties with the right to use the patent. In this case, the patent holder retains the ownership of the patent. Patent holders can also sell the patent rights. They use, instead, the patent strategically when they prevent others from using the invention. Finally, quite a few patents are left unused. These five uses are not mutually exclusive.. For example, owners may use the patent internally, but also license it; or they can prevent others from using the invention, but they also use it.

The InnoS&T survey is one of the few datasets that provides a comprehensive assessment of the use of patents. As discussed earlier, this dataset covers 23,044 representative EU patent applications with priority dates 2003-2005 by inventors located in 20 European countries, Israel, Japan, and the US. Torrisi et al. (2016) provides a comprehensive description of the survey and its data. It focuses on the uses of 8,144 patents by firms or individuals in the survey. The drop in observations stems from the focus on firms and individuals and on missing observations on some questions. While this may introduce some bias in the representativeness of the sample, we believe that, given that the original sample is representative of the EU patent applications, these biases are not dramatic.

Table 5 reports the shares of *commercial use*, *strategic non-use*, and *sleeping patents*. Commercial use distinguishes between *internal use* by the applicant to product goods and services, patent *licensing*, *sales* of patent, or whether the patent was used to create a *start-up*. Torrisi et al. (2016) defines strategic non-use as patents not used commercially and such that the respondents check 4 or 5 (important or very important) on a 1-5 Likert scale to the question whether the motivation of the patent is to block rival innovations. Of course, respondents may tick 4 or 5 to patents used commercially in one of the forms indicated above. However, strategic non-use only denotes cases in which this motivation comes with the non-commercial use of the patent. Sleeping patents denote patents not used commercially and not motivated by blocking rivals (1-3 on the Likert scale.) The table also distinguishes among small firms (less than 100 employees), medium firms (100-250 employees) and large firms (> 250 employees.)

The table shows that commercial use accounts for 60.6% of the patents, strategic non-use for 26.3%, and 13.1% are sleeping patents. Commercial uses focus mostly on internal use. However, licensing or sale account for a sizable fraction, over 10%, and 4% of patents are used to create start-ups.

Table 5: Uses of patents by firms

	Commercial Use (%)			**Strategic non-use (%)**	**Sleeping (%)**
	Type of commercial use	%	Total		
Small firm (< 100 empl.)	*Internal use*	66.0	76.5	14.5	9.0
	Licensing	16.7			
	Sale	12.2			
	Start-up	17.9			
Medium firm (100-250 empl.)	*Internal use*	73.9	77.0	15.5	7.4
	Licensing	8.6			
	Sale	4.3			
	Start-up	5.6			
Large firm (> 250empl.)	*Internal use*	54.8	56.2	29.5	14.3
	Licensing	2.7			
	Sale	4.2			
	Start-up	1.0			
Total	*Internal use*	57.6	60.6	26.3	13.1
	Licensing	6.4			
	Sale	4.3			
	Start-up	4.0			

Based on 8,144 EU patent applications by firms and individuals from the InnoS&T survey. Use of patents defined by responses to survey questions. Commercial use = respondents state that patent was used internally, licensed, sold, or for creating a start-up. More answers are possible. Strategic non-use = respondents state that blocking rival is an important reason for patenting (4 or 5 on 1-5 Likert scale) and patent is not used commercially. Sleeping = complement to strategic non-use and patent not used commercially. See Torrisi et al. (2016) for details.

The most important differences are across firms of different sizes. SME exhibit a higher rate of commercial use of patents (over 3/4th), while large firms use slightly more than 50% of their patents. Large firms show a systematically higher share of unused patents for both strategic and non-strategic reasons. All this is not surprising. Large firms invest sizable fixed costs in R&D. They generate more innovations at lower marginal costs, and thus select which innovations they develop. Smaller firms are instead more focused in their R&D strategies, and they are more likely to use their patents.

The more striking differences, however, regard the licensing strategies. Overall, small firms license or sell nearly 30% of their patents vis-à-vis nearly 7% by large firms. Medium firms are in between: they license or sell circa 13% of their patents. This evidence is consistent with our discussion in the previous section: small firms have a comparative advantage in licensing or selling their patents to firms with stronger production and commercialization assets.

Since large firms produce more patents, even if they license or sell only 7% of their patents, they provide the market with a greater supply of technology. This simply suggests that the market for technology is populated by both small and large firms. Moreover, Bloom et al. (2013, Table IX) show that large firms create more technological spillovers than smaller firms. Their patent licensing and sales are then one vehicle that can give rise to these spillovers. At the same time, small firm generate the classical benefits of a division of labor based on comparative advantages. Moreover, because they have limited commercialization assets, they are less likely to compete with their buyers in the product markets, making buyers less concerned about purchasing technologies from them.

This also raises the question whether the value of the patents offered in the market for technology is lower than the value of patents that companies use internally, and whether this wedge is different for small and large firms. We use the InnoS&T data to answer this question. Table 6 reports the estimated value of patent rights, for which we have information on value in the InnoS&T survey that are either used internally, or licensed or sold, by small, medium and large firms. We focus on these patents because, given that they are used, the inventors probably have an anchor to assess value more credibly. Since InnoS&T reports the value of all the set of interconnected patents, we looked at the average value of patents in the portfolio. However, the results are the same if we look at the portfolio made of one patent, for which the average value is the exact value of the patent.

Table 6: Value of patents used internally vs licensed or sold

	Average value of patents in the portfolio (000 euros)		**Total citations**	
	Internal use	Licensed or sold	Internal use	Licensed or sold
Small firm (< 100 empl.)	Mean = 9873 Median = 650 Obs. = 874	Mean = 9057 Median = 650 Obs. = 473	Mean = 0.86 Median = 0 Obs. = 1062	Mean = 1.46 Median = 1 Obs. = 548
Medium firm (100-250 empl.)	Mean = 8115 Median = 267 Obs. = 361	Mean = 4475 Median = 650 Obs. =74	Mean = 0.83 Median = 0 Obs. = 460	Mean = 1.38 Median = 0 Obs. = 95
Large firm (> 250empl.)	Mean = 6607 Median = 260 Obs. = 3494	Mean = 5513 Median = 333 Obs. = 537	Mean = 1.15 Median = 0 Obs. = 5033	Mean = 1.33 Median = 1 Obs. = 716

Based on EU patent applications by firms and individuals from the InnoS&T survey that were either used internally or licensed or sold. Average of value of patents in the portfolio of the focal patent that was internally used or licensed or sold. Total citations refer instead to the focal patent.

The table shows no clear difference in value between patents used internally, licensed or sold. We show both average and median because the skewed distribution of value suggests that the mean may be affected by outliers at the right tail. The table shows quite some variability. However, there is no clear pattern. The table reports the same information for the total citations of the focal patent. Again, no clear pattern emerges; if anything, licensed patents seem to have slightly more citations on average. Overall, we can conclude that patents transacted in the market for technology do not seem to be less valuable than patents used by firms internally.

Small firms also use a larger share of their patents to launch start-ups. Table 5 showed that 17.9% of their patents are associated with the creation of a start-up vis-à-vis 5.6% and 1% in the case of medium and large firms. This is a manifestation of the same phenomenon. On the one hand, small firms have a greater comparative advantage in creating new firms that pursue specific technological opportunities; on the other hand, many of them are probably themselves the start-up generated by the patent. At the same time, again, even if only 1% of large-firm patents generate start-ups, the higher number of large-firm patents implies that they generate quite a few start-ups. Therefore, like for patent licensing or sale, both small and large firms can actively contribute to the rise of start-ups from patents.

More generally, all this suggests that, apart from internal use, patented inventions can encourage the diffusion of technology in the form of technology markets or creation of new firms. Both large and small firms can be active suppliers in these markets, or they contribute to innovation by creating new firms.

Finally, we confirm these patterns using information about the motivations for patenting of firms of different sizes. Torrisi et al. (2016) show data on the motivations for patenting of the 8,144 patents of firms and individuals in their InnoS&T sample. We report these data in Table 7.

The table shows that commercial use and prevention from imitation are by far the most important reasons for patenting, with small differences across firms of different size. Thus, firms of any size patent primarily to exploit innovations commercially and to protect themselves from imitation. If anything, the motivations for commercial use and prevention of imitation are slightly higher for small firms. This confirms that small firms have stronger incentives to patent to exploit the innovation and they are more concerned about imitation.

Licensing is more important for small firms then large firms, while cross-licensing is more important for large firms. This suggests that small firms are motivated by licensing, while large firms tend to barter licenses in cross-licensing deals. Torrisi et al. (2016) report that the motivation for cross-licensing is higher in the electrical engineering macro-sector (which includes electronics). As well known, cross-licensing is typical of the broadly defined electronics industry. The importance of licensing for small firms is sizably more important than the importance of cross-licensing for large firms. This strengthens the perspective that licensing represents an important strategic option of small firms. The table also shows that patenting just for blocking rivals is relatively more important for large firms.

3.3 Patents and the diffusion of innovation

3.3.1 Patents as signals

An important function of patents is that they offer an independent assessment on the innovation potential of firms and inventors. Innovation and innovation capabilities are surrounded by uncertainty. In general, it is difficult to predict the ability of a firm or inventor to produce innovations. Past information helps, but in the case of innovations a good deal of the inputs to the innovation process are intangibles, such as experience, dedication, or ability. Signals can then help to evaluate potential performance better.

Table 7: Motivation for patenting by firms (Likert scale: 1-5)

	Commercial Use	Licensing	Cross-licensing	Prevent imitation	Block rivals
Small firm (< 100 empl.)	4.57	3.53	2.30	4.22	3.62
Medium firm (100-250 empl.)	4.45	2.76	2.17	4.23	3.74
Large firm (> 250empl.)	4.32	2.86	2.80	4.10	3.87
Total	4.37	2.96	2.69	4.13	3.83

Based on 8,144 EU patent applications by firms and individuals from the InnoS&T survey. Average of the 1-5 responses (1 = not important; 5 = very important). Multivariate tests of differences across means by firm size statistically significant at p < 5%. See Table 3 in Torrisi et al. (2016),

Clearly, the problem is more important for firms or inventors for whom we do not have good past information. For larger and more established firms this is a lesser concern. The concern is more serious for new firms. To the extent that new firms and entrepreneurs are important vehicle of economic growth, the potential of patents to improve the evaluation of these firms has important implications for our societies. Better evaluations help investors to make more productive investments by picking the right firms for financial support or acquisition.

Hsu and Ziedonis (2013) provide evidence of the signaling function of patents. Using data on 370 venture-backed start-ups in the semiconductor industry, they show that firms that hold patents receive greater support in their early stages and when their founders have less experience and are less known. This qualification is important. If the effect was relevant in other stages and for more experienced founders, we would be unable to distinguish between the classical property function of patents and its signaling function. Start-ups could receive greater support simply because patents imply that they own relevant economic assets. The fact that this effect is stronger in earlier stages and for less reputed entrepreneurs, for whom, presumably, investors have less information, suggests that the signaling function also matters.

The InnoS&T data confirm this perspective. Another motivation for patenting is reputation. In Torrisi et al. (2016, Table 3), reputation as a motivation for patenting obtained an average index of 3.19 for small firms, 2.96 for medium firms and 2.78 for large firms. These differences are all statistically significant. While Hsu and Ziedonis show that investors use patents to make evaluation of firms for which they have less information, InnoS&T shows that small firms realize this opportunity and are motivated to patent for this reason as well. Small firms seem to understand that, for them, patents have value as signals. The incentive is smaller for larger firms that do not have a similar need to establish their reputation.

Farre-Mensa et al. (2020) extend both the representativeness of the analysis and the results of Hsu and Ziedonis (2013). They use data on 34,215 first-time applications filed by US start-ups since 2001 that received a final decision by December 31, 2013. Their methodology uncovers the causal relation between patents and the performance of new firms. They find that the grant of a patent increases considerably firm's growth, sales, employment, and future patented inventions.

They confirm that patents affect the chances of VC and IPO financing, as well as the chances of getting a loan using patents as collateral. Moreover, this effect is stronger for the first patents and when the entrepreneur is less experienced, making the evidence about patents as signals robust. They also find an important effect of patents in securing subsequent rounds of financing after the first one. Farre-Mensa et al. (2020) interpret this finding as evidence that the property rights of patents also matter.

The more general point is that patents contribute to the rise and performance of high-quality small firms. They also help these firms to secure financing, which further helps their growth. Apart from the benefits accruing to the individual firms, we noted that the rise of new firms, and more transparent markets for supporting them, have social value. Therefore, patents contribute to the creation of this social value.

3.3.2 Patents and disclosure

Patents provide another important function, and this is that they disclose the content of the invention. This is inherent in the "social" contracts associated to patents: society offers exclusivity to the patent holder in exchange for the disclosure of the invention. As noted by Fromer (2009, p.539), such disclosure "indirectly stimulates others' future innovation by revealing to them the invention so that they can use it fruitfully when the patent term expires and so that they can design around, improve upon, or be inspired by the invention both during and after the patent term." (See also Cohen et al., 2002.) Today information about patents is easy to find in computerized databases, and we have several useful statistics about them, including proxies for quality such as citations, claims and other such measures. As noted, we can increasingly use natural language processing technologies to search content in patent texts.

The literature on the potential benefits of the disclosure function of patents is growing. Gross (2019) uses data on 11,000 US patent applications subject to a secrecy program during World War II that prevented inventors from disclosing their inventions or filings. The study shows that this program reduced follow-on invention and restricted commercialization.

Furman et al. (2021) study the expansion of US patent libraries between 1975 and 1997. In 1975 there were 20 patent libraries mostly in New England and to the East of Mississippi. In the same year the US Patent Office decided to embark on an effort to open at least one patent library in each US State in order to facilitate the consultation of patent documentation by inventors, attorneys or any other individuals. Furman et al. (2021) show that, on average, the opening of a library increased the number of patents produced within 15 miles from the library between 8% and 20%. The 15 miles range suggests easier access to the library, making it more credible that the availability of information has produced the effect they estimate. In this respect, they also show that the effect is weaker beyond 50 miles. They also find that the new patents after the opening of the library are not of lesser quality, suggesting that the new information has not produced less important innovations.

Furman et al. (2021) provide additional evidence suggesting that the disclosure of patent information is the mechanism of the effect that they observe. First, the increase is more pronounced in chemicals, where innovations are more likely to build on information about previous innovations. Second, the new patents produced after the opening of the library are more likely to use new words not used by previous local patents, but that are used by patents in other regions. This suggests that the new local patents are more likely to be affected by information about these geographically distant patents. Third, they find that the opening of libraries impacts new and old teams of inventors in the same way. These rules out the alternative explanation that the opening of libraries facilitated information exchange among inventors who did not interact before and now can meet in a common place, favoring the creation of new teams of inventors.

A stronger opportunity to identify the effects of disclosure comes from the introduction in 1999 of the US American Inventor's Protection Act (AIPA), that required publication of the content of the patent 18 months after filing for all patents filed on or after November 29, 2000. Before AIPA, publication occurred only after grant. This anticipated the time of publication that before AIPA had a lag of 3.5 years from filing. Basically, AIPA accelerated disclosure.

Hegde et al. (2020) uses this quasi-natural experiment to show that this acceleration in disclosure has had several interesting effects. This is a rigorous study that compares US patents before and after AIPA with twins European patents not subject to this shock. The study then disentangles the causal effect of disclosure through a difference-in-difference approach.

First, the study finds that disclosure increases the citations of other patents, suggesting that patented inventions build to a greater extent on one another. Second, citations occur more rapidly, suggesting that disclosure increases knowledge spillovers. Third, technological distance increases between technologically closer patents and decreases between technologically distant patents. This suggests that, on the one hand, research builds to a greater extent on extant research, and, on the other hand, it reduces potential duplications. Finally, patents are less likely to be rejected and increase by circa 6%.

To be sure, while patents have a positive effect on future patents because of the disclosure of invention, they could discourage follow-on innovations because other parties may have to obtain authorization to commercially exploit incremental innovations from the owner of the original patent. The importance of this follow-on effect is still an open question that patent scholars have not yet been able to nail down unambiguously (Williams, 2017).

Two of the most careful empirical studies on this topic are Galasso and Schankerman (2015) and Sampat and Williams (2019). Galasso and Schankerman (2015) use the random allocation of judges to patent cases to compare counterfactual invalidated and non-invalidated patents litigated in courts. Invalidated patents still represent prior art, and therefore they are still cited by future patents. Galasso and Schankerman (2015) then show that invalidated patents, which lose the patent rights, are more likely to be cited than their counterfactual non-invalidated patents. While patent citations could reflect strategic choices of firms, typically made by patent attorneys (Corsino et al., 2019), the conclusion of this study is that patent rights may discourage innovations that build on them.

In contrast, Sampat and Williams (2019) do not find important limitations of follow-on innovations in the particular case of patents on human genes. Galasso and Schankerman (2015) also find heterogeneity of the follow-on effect across technological fields. Moreover, their analysis focuses by construction on patents litigated in courts, which is a selected sample of patents. They also show that the observed effect is produced only by invalidated patents of large firms, and the citations typically come from small firms. Overall, this confirms that the average effect of patents on follow-on innovations is ambiguous, albeit their heterogeneity across technological fields and patent owners.

At any rate, there is a difference between the effect of patents on follow-on innovations and the effect of patent disclosure. The former depends on the classical function of patents. Because patents provide the right to exclude others from using the invention, they may discourage follow-on innovations that may infringe the focal patent. The latter depends on the fact that the information provided by the patent encourages innovations spurred by the diffusion of the information about the patented invention. Clearly, the two effects are related. If patent rights discourage follow-on innovations, the information provided by the patent is less useful to produce new patents.

However, to summarize, while we have an ambiguous average effect on follow-on innovations, the disclosure effect appears to be less ambiguous. It seems to produce more patented inventions, innovations of higher quality, and greater spillovers among them. It also generates greater coordination, both in the form of fewer duplications of research and greater accumulation of knowledge from previous research. Simply put, the disclosure functions of patents appear to be important.

3.3.3 Patents and markets for technology

Patents contribute to the rise of markets for technology in which producers of innovation license or sell their technological outcomes to other firms that produce and commercialize the goods. This is a potentially efficient process in that the abilities and organizational structures that are most effective in producing innovation are not always the best ones to produce and commercialize the goods. The former typically require more flexible and flatter organizational structures that encourage creativity. The latter require instead more hierarchical organizations and incentives to enhance efficient routines.

We have known for a long time that we are more likely to find these incentives and organizational structures in smaller than large firms (Arrow, 1962; Holmstrom, 1989). Of course, this does not mean that all small firms are ideal for innovation and large firms are not. Moreover, large firms can create separate internal entities for these purposes. This may create internal conflicts, but the more general question is not whether large firms can organize innovation activities internally, which they do, but whether markets for technology increase the generation and diffusion of innovations, benefitting the large firms as well. There is substantial evidence that large firms also benefit from the independent supply of technology (Arora et al., 2001).

In fact, small firms are unlikely to be more productive in absolute terms than the large firms in the innovation process. For example, Arora et al. (2009) estimate that large pharmaceutical firms are more productive than many smaller biotechnology companies in the discovery process in pharmaceuticals. However, they are all less likely to develop many of the new compounds that they produce because it is more profitable to concentrate resources on the development of the best innovations.

Moreover, they have fewer incentives to develop potentially competing innovations in parallel, or innovations that can compete with their own products, which is the standard argument about the "cannibalization" of innovations by Arrow (1962) and Holmstrom (1989). In this respect, what is more important from the point of view of the value for society is that smaller firms have a comparative advantage in supplying technology, which makes the underlying division of labor between large and small innovative firms efficient. Of course, active markets for technology imply that large firms too can operate in them as suppliers of technology, and not just as buyers.

Teece (1986) first noted that organizations can exploit their innovations either internally, by carrying out the production and commercialization of goods and services, or by providing others with the right to use the technology. He pointed out that internal exploitation depends on the ownership of complementary assets for production and commercialization. In other words, internal exploitation is typical of larger established firms that have these capabilities. The incentives to license or sell the technology depend instead on the extent to which the technology suppliers can appropriate the returns from the transaction. Teece argues that patents are crucial because without them buyers can take advantage of the technology, even if the parties do not conclude the transaction.

The antecedent of this insight is that contracts for the exchange of knowledge are hard to write (Teece, 1988). These contracts are inherently ambiguous and incomplete because the object of the contract (an innovation, a new piece of knowledge) cannot be defined *ex-ante* in detail. This makes the contract ambiguous and incomplete. Moreover, even if the object of the transaction can be defined in the contract, Arrow's (1962) insight that it is hard to exclude others from using information implies that the sellers are subject to the risk of opportunism on the part of the buyer.

This reduces the incentives of sellers to supply their technology in the market. If they have the capability to exploit it internally, they will do so rather than selling the technology, even if it is more efficient to sell rather than integrating them. For example, smaller firms, which do not have a comparative advantage in integration into the applications, will do so rather than offering this opportunity to larger firms that have these comparative advantages; and if smaller firms do not have the capabilities to produce the applications, they will not produce the innovations in the first place. In both cases we either have an inefficient exploitation of technology, or we have a lower rate of innovation in the economies.

Arora (1995) discusses how we can create incentives to write efficient contracts for the supply of technology, and the role of patents in these contracts. Contracts for technology exchange are typically composed of two parts. On the one hand, suppliers sell a codified component of the technology, such as a design or a blueprint, that can be protected by a patent; on the other hand, they sell complementary services that cover tacit components such as expertise in using the technology. Arora (1995) shows that an ideal contract has two installments. The buyers first provide an initial installment for the supply of the codified part of the technology. Then, the suppliers provide the know-how in the form of services such as training or other similar activities. After the supply of the know-how the buyers pay the second installment.

Patents play a crucial role in this process. The tacit component of the supply is hard to protect and to nail down in the contract because it requires unobserved efforts and activities on the part of the suppliers. At the same time, if the suppliers put the right effort, they run the risk that after buyers learn from them about the use of technology, buyers can renegotiate opportunistically the second payment claiming breaches of the contract that cannot be proven in courts because of the contract's ambiguities and incompleteness. However, if the codified component of the technology is protected by a patent, and the contract establishes that the suppliers provide the right to use the patent only after the second installment, the suppliers can deny this right. If the buyers are unable to use the codified components, unless they infringe the patent, the value of using the tacit component may be severely undermined.

This provides the suppliers with a tool that balances the potential opportunism of the buyers, reducing their incentives to renege the contract. At the same time, if the second installment is sufficiently large, the suppliers have the right incentives to provide the right amount of know-how. Thus, overall, a proper balance of the two installments, along with patent protection, can provide the right balance to make these contracts viable. Clearly, if the buyers do not need the supply of services, the first installment concludes the contract. However, the protection provided by patents is still important because buyers could use it without providing the suppliers with a fair price for the technology.

Arora et al. (2001) and Gans et al. (2002) provide extensive evidence that when firms have complementary resources to produce and commercialize the final goods, they integrate their innovations in these final applications. However, they also provide evidence that the lack of these capabilities encourages the suppliers to sell their technologies only if they can appropriate their returns because they are protected by patents. In particular, Arora and Ceccagnoli (2006) use systematic data on the licensing strategies of US firms. They show that protection encourages technology licenses and this incentive is stronger in the case of firms without manufacturing capabilities.

All this squares with our discussion in the previous sections. Patents encourage in particular the productivity of small firms and their incentives to license. To the extent that these firms are vehicles for innovation and growth, patents serve this wider purpose in our societies. Moreover, there is growing evidence that patents provide related functions associated to markets for technology.

Gans et al. (2008) show that most patent licensing occurs at the time of the patent grant, which, they argue, is associated with the reduction of uncertainty about claims and the extent of protection. Again, this points to the fact that clear property rights help technology trade. Hedge and Luo (2018) use the AIPA quasi-natural experiment to show that post-AIPA patents are more likely to be licensed. This suggests that the disclosure function of patents makes market for technology more transparent and more efficient. Finally, markets for technology raise the opportunity to use patents for other purposes. Hochberg et al. (2018) show that when markets for technology function well, and patents are salable, they can be used as collaterals in funding deals, raising the opportunities of funding and the transparency of the funding process.

Galasso et al. (2013) use data on patents owned by individual US inventors and show that not only do the benefits of a division of labor in technology markets depend on comparative advantages in the generation of innovation, but also on comparative advantages in the enforcement of the property rights. They argue that only the relatively more valuable patents of individuals are traded, and because they are more valuable, they are also more likely to be litigated. Empirically, they show that, indeed, these patents are more likely to be litigated. Moreover, they show that, when the risk of litigation is higher, patents are more likely to be transferred to large firms, which have a stronger ability to enforce them, and this makes them less likely to be litigated.

Since they focus on individual US inventors, it is hard to generalize whether the efficiency of the division of labor depends on a comparative advantage in the ability to generate innovations or to enforce patent rights. However, in both cases, this is an efficient outcome because either it allocates resources according to the ability to produce or exploit innovations commercially, or to counter litigation, and therefore reduce costly litigations in patent trade. As a matter of fact, Galasso et al. (2013) show that inventors enjoy higher gains from patents trade, and the underlying division of labor increases their incentives to innovate.

Markets for technology have started to rise since the end of the XX century. Athreye and Cantwell (2007) collected systematic data on licensing receipts and showed that they increased sharply since the 1980s, along with an increase in patenting. Graham et al. (2018) show similar signs of increase in patent transactions in the first decade of the new millennium. However, they also document that the increasing trend might have come to an end.

According to Arora et al. (2001), the rise in markets for technology stems from several concomitant factors. The growing role of software and the scientific of industrial activities have contributed to the codification of a good deal of industrial knowledge and innovations. This has made it easier to define the object of innovation, which has had, in turn, two implications. On the one hand, it has made imitation easier; on the other hand, it has made patentability easier because it is easier to identify the object of protection. This has created the opportunities to identify technology, eased the object of transaction, and eased the way to protect it. In addition, software and the greater scientific-intensity of industrial knowledge have encouraged the creation of general-purpose technologies (GPT). These GPT have potentially more applications than the producers can pursue, encouraging them to supply them to others.

As widely documented (e.g. Arora et al., 2001; Hall and Ziedonis, 2001), the opportunity to supply technologies through markets has become a valuable strategic option for smaller firms. This, however, is also the potential explanation for the tapering off of these markets in recent years. As discussed in the previous sections, large firms hold most patents. Thus, the ability of small firms to feed this market has limits. Only if the large firms also become suppliers in this market, we can expect them to grow further.

3.3.4 Patents and GPT

The supply of GPT is another important angle of our discussion. GPT play an important role in that they can give rise to considerable benefits for society because they have vast applications. The question is whether patents provide greater incentives to produce them, or they monopolize knowledge that has wide potential uses with the implication that owners of GPT patents can concomitantly several applications, including those that the owner does not develop. The answer to this question is not easy. We can provide elements in favor and against it, and the best way to proceed is, as usual, to find the ideal solution to this trade-off.

Gambardella and McGahan (2010) show that with dedicated technology, appropriability is the only way to earn bargaining power and rents in technology transactions. The technology can only be supplied to a small number of firms and industries. This reduces bargaining power and thus the ability to gain rents in transactions. Conversely, GPT widens the potential buyers, including buyers in distant product markets. Bargaining power still depends on individual transaction, but the upside is that suppliers can sell the technology to several distant buyers. Thus, even if they earn small rents from each buyer, they can enjoy profits by selling to many of them. In other words, they can shift from earning profits thanks to the intensive margin, for which they need bargaining power, to earning profits thanks to the extensive margin, for which they can rely on their ability to find new applications, as opposed to their bargaining power in each transaction.

The shift from the bargaining power in each transaction to the ability to find new applications switches attention from the property rights on the core invention to the ability to produce innovations, which is *de facto* the search for new applications. Finding new applications imply, for example, alliances and collaborations with many firms and industries, and therefore it is a costly activity (e.g. Thoma, 2009). This is itself hard to do without some form of protection in the basic technology. Moreover, Conti et al. (2019) show that the opportunity to develop GPT often comes with the incentive to abandon the markets of applications, becoming a specialized producer of the GPT. This reduces the downside of GPT patenting because the owner of the GPT does not have an incentive to monopolize the application markets.

Using the InnoS&T data, Gambardella et al. (2021) confirm Teece's original intuition that the appropriability provided by patents raises the incentives of firms to license dedicated technologies. They find a mixed effect for GPT. For some industries and firms, the strength of appropriability is less important to motivate the licensing of GPT; in others it is still important. This mixed finding is consistent with our discussion. Simply put, even if they do not own production and commercialization assets, the producers of GPT do not rely only on protection, but can take advantage of their ability to find new application firms or industries to which they can sell their technology.

At the same time, it is hard to think that we cannot provide GPT producers with some form of protection. Apart from protecting them from imitation, patenting protects them from the risk that other patents, either some version of the unpatented GPT, or some applications, block their ability to exploit the GPT commercially. Moreover, GPT patents serve as signals. For example, holders of these patents can use citations to patents coming from different firms and industries as independent evidence of the GPT nature of their technology, with implied opportunities to secure funding or to highlight the quality of the firm and its outcomes. Similarly, disclosing GPT patents helps, nearly by definition, follow-on innovations. Of course, the tradeoff is that patent examination, and policies more generally, ought to pay special attention to avoid that they add scope to these patents that already have a potentially wide scope.

4. EVIDENCE-BASED MANAGEMENT AND POLICIES FOR PATENTS

The gist of this article is that patents have many functions and play many roles in modern societies. This produces some trade-offs.

The classical trade-off is embedded in the primary function of patents. Society offers the opportunity to privatize knowledge to restore economic incentives to produce it. Society is careful about this attribution of rights. It does not want these rights to be too strong to avoid excessive monopolization of knowledge and invention, and when knowledge is more basic and more scientific, it wants the knowledge to stay in the public domain and the underlying research supported by public resources.

A second trade-off is that while patents privatize inventions, they also accomplish socially valuable functions. They facilitate diffusion of innovation through markets for technology, they can provide signals that ease the evaluation of innovations and firms, or they disclose information about inventions that spurs other innovations.

However, the overall evidence we have so far about the value of patents for society is still imprecise, and the best response to it is to provide more and deeper evidence about the effects of patents. Ohlhausen (2016) provides a comprehensive assessment of studies that discusses the potential upsides, and not just downsides, of patents. However, more generally, we need to understand better the effects of patents by conducting several systematic studies on these effects. From here, we can understand how to improve the value of patents for society by better optimizing the classical trade-off of patents and by enhancing their social functions.

Scholars have studied patents widely. However, because patents are a complex topic, we need more studies than a simpler topic that can generate unambiguous evidence in a more straightforward way. In particular, the complexity of the many implications of patents suggests that it is difficult to produce reasonable estimates of the “net overall” effect of patents – that is, a study that concludes, in general, whether patents are valuable or not for society. The many effects and implications of patents suggest that such a statement is probably not even testable. A more effective exercise is to encourage several studies that focus on specific effects. By developing many of these studies, we can produce a detailed map of problems and potential solutions to undertake evidence-based managerial or policy actions. As noted above, this could help to optimize better the trade-off between private and social functions of patents.

In this respect, a step forward compared to current contributions is to encourage more studies that start from relevant questions about patents rather than available data. This is a tricky statement that needs to be explained. While data about patents abound, not all relevant data are available. Thus, available data drive a good deal of the current studies. In particular, we do not always have data about counterfactuals to identify causal mechanisms that we are interested in.

To be sure, quite a few patent studies have addressed relevant questions, and they have provided good identification, especially in recent years. Scholars have exploited quasi-natural experiments produced by policies, laws, new interventions (such as AIPA), or they have devised intriguing identification strategies (e.g., random assignment of judges or patent examiners). However, we can only address questions about causality that exploit the events that we can find. In fact, scholars have sought events that helped them to address relevant questions. But we can do better: we can start with the questions and then design data collections or experiments that enable the researchers to answer them. Otherwise, we neglect relevant questions simply because we do not have the right data or design.

Agencies that manage and collect data about patents play two important roles in this process. First, together with relevant stakeholders and institutions, they can help to raise relevant questions. Second, they can help to collect data or to design experiments that address them. It is hard to indicate here which specific data should be collected or which experiments should be run. But we can suggest criteria.

First, as noted, we need more causal studies. So far, the available data about patents are largely produced for general information and description, not to make prediction or decisions. Sometimes descriptive data are useful for predictions because predictions may simply require correlations. However, data to make decisions require that we understand causes and mechanisms because the outcome of a decision depends on the deployment of these mechanisms. Thus, the process ought to start from the questions, and then move to data collection or to the creation of the conditions for causal identification of the underlying effects.

Patent Agencies or other relevant stakeholders or institutions can help researchers to think and design analyses that allow for these identifications of mechanisms that answer specific questions. They can then help to collect data for these studies in two ways. On the one hand, they can collect data that provide the exogenous variations needed for identification. On the other hand, they can design and run experiments. This requires that, for relatively small samples, they deliberately change conditions in the patenting process for a treatment group and compare outcomes with a control group using classical difference-in-difference experimental analyses. Today, an increasing number of organizations (government or firms) are using experiments to understand better the actions they can take (Luca and Bazerman, 2020). These experiments can inform policy and managerial actions about patents both in companies and the Patent Offices.

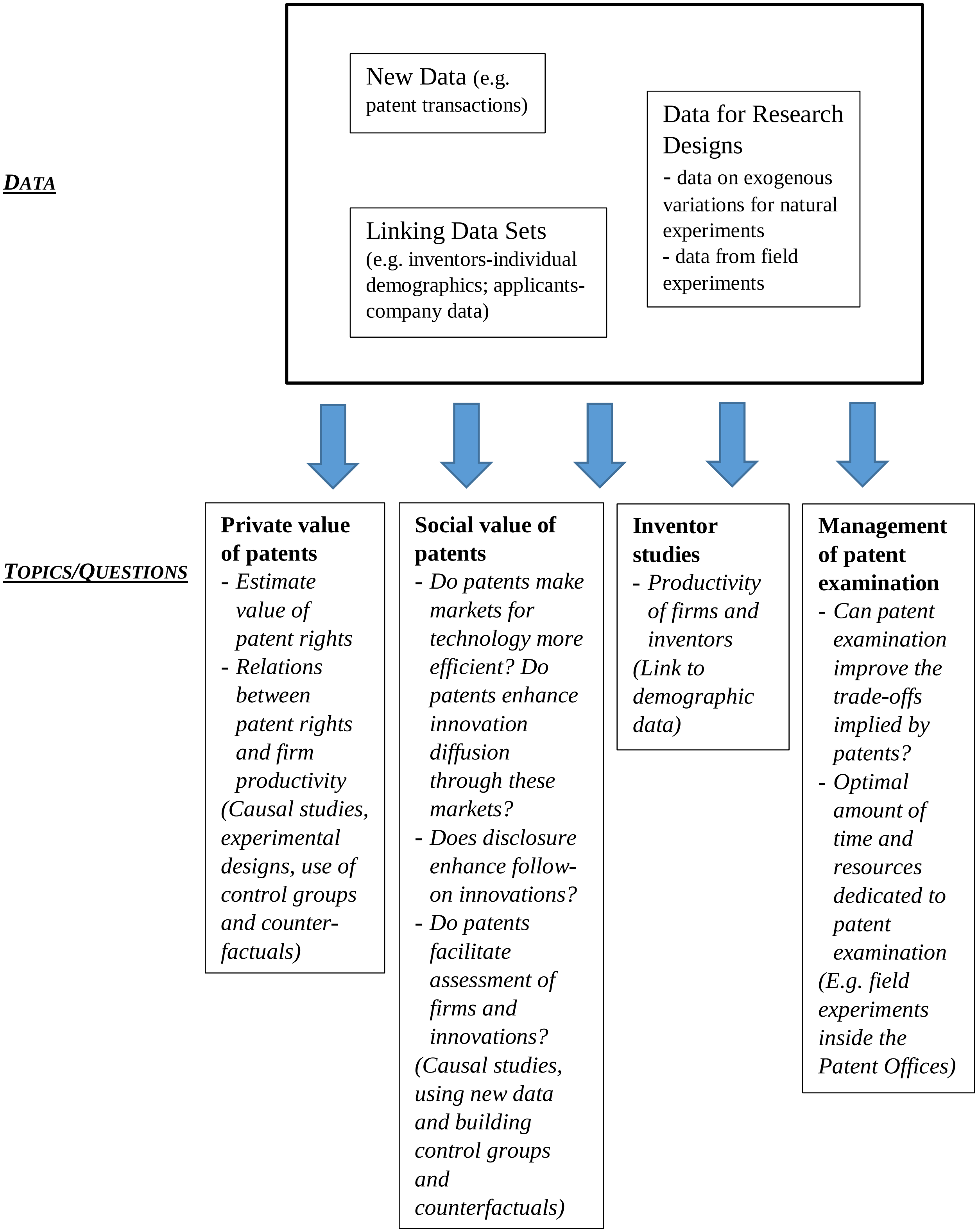
Second, this article helps to identify areas in which we can raise relevant questions about patents. Figure 2 provides a visual representation of potential actions for data collection and topics or questions. There are three main activities to produce relevant data about patents: 1) collection of new data to address specific questions, such as data on patent transactions to better understand markets for technology; 2) collection of data on exogenous variations and design of corresponding natural or field experiments; 3) links between patent data and other datasets (e.g. applicants or inventors). These activities and data can then feed into four areas of topics and questions.

In line with the discussion in this article, the first two areas are *value of patent rights* and *social functions of patents*.

First, we need to understand and estimate better the value of patent rights. We discussed some studies (in particular Kogan et al., 2017). However, the value of patent rights differs considerably across context and conditions. We need to understand these differences better especially because they may underlie different mechanisms and determinants. Understanding this heterogeneity is crucial for a better understanding of the problems and to devise actions focused on specific problems or conditions.

Second, we need to understand better how patent rights affect the performance of firms. As a concrete example, consider the OHIM (2015) and EUIPO (2021) studies discussed in Section 3.1. These studies use large representative samples of European firms to show that patents increase labor productivity, particularly of small firms. As the studies acknowledge, these are correlations, and thus we cannot conclude that patents cause the effects that we observe. If we showed instead that the relation is causal, we could draw policy conclusions – for example that helping small firms to protect their inventions through patents increases their productivity. If it was only a correlation, this policy would not improve the productivity of small firms. Suppose that the correlation stems from the fact that innovations raise the productivity of these firms, and patents proxy for their ability to innovate. In this case, policies that support patenting of small firms will not increase their productivity.

Figure 2: Research designs and patent data collections in patent economics



Third, relevant data or designs of experiments can shed more light on the social function of patents, from markets for technology to questions about the implications of disclosure or the signaling value of patents. There is no need to go in detail here, but it is clear from the discussion in this article that there are several opportunities.

As far as markets for technology are concerned, we need to understand better how these markets work (e.g., the bargaining process, or other aspects of their nature and functioning), how we can make them for efficient, or how they can contribute to increase the diffusion of innovation or their value. Here again there will be heterogeneity depending on markets, the parties involved, the types of patents or technologies.

As a concrete example, the process could start from addressing, using theoretical arguments, where we expect the effect of markets for technology to be most important (e.g., which types of firms, technologies, or contexts.) Then, relevant stakeholders and institutions could help to collect data on patent transactions, the parties involved, and other characteristics of the domain under consideration, as well as identify and collect the same data for a control group of counterfactual patents to make causal comparison. One could then move to other similar contexts and processes where we believe, from theory, that it is important to provide evidence about markets for technology.

The same logic and process could be applied to other topics, particularly the disclosure or signaling effect of patents, or the impact of patents on follow-on innovations. In this respect, it is important that these designs focus on relevant contexts suggested by an ex-ante assessment of the problem. As discussed in this article, and extensively by the literature, the effects of patents are heterogeneous, and it is probably not that effective to think of average, overall effects of patents. We may obtain more effective insights by studying different specific context where we expect that the effects may actually differ.

Figure 2 suggests two other realms of analysis. One is the analysis of inventors. This is another relevant topic, even though it does not have to do directly with the role of patents as providers of property rights. However, understanding the productivity of the inventors is likely to have important impacts on our understanding of the productivity of the innovation process. For example, the recent paper by Bhaskarabhatla et al. (2021) shows that inventors' human capital is 5-10 times more important than firm capabilities for explaining the importance of inventor output.

Since standard patent data focus on patents not inventors, they do not provide demographic or other information about inventors. This information can help to address important questions about the productivity of inventors and the inventor process. Leading studies in the US (e.g., Bell et al., 2019) have linked information about inventors in patents with individual information from the Census or tax profiles.

Compliance with privacy policies and the European GDPR is a must in this area. However, on complying with the rules, society will benefit from a better understanding of the determinants of the productivity of innovation and the role of patents in this process. For example, Bell et al. (2019) used de-identified data of 1.2 million inventors linking patent and tax records. Moreover, such linked datasets could cover control groups of individuals or inventors to create adequate designs that identify theorized effects associated to relevant questions about the innovation process.

Finally, Figure 2 suggests that one important area of research is the management of the patent examination process. Guidelines about patent examination represent concrete implementations of patent policies. For example, if rigorous studies show that, under some conditions, patents ought to be narrower in scope, patent examiners can implement stricter policies by adopting more stringent criteria about claims or scope. Of course, this is what patent examiners already do, but society may benefit, more generally, from clear guidelines stemming from rigorous studies that provide the basis for evidence-based management and policies.

Moreover, data on the patent examination process offer additional opportunities to understand causal implications about different effects, and then answer important questions about the implications of patents. Collecting the right data and implementing the right research design can help to address quite a few questions that are currently unanswered. Also, an overarching question in this area is whether society needs to invest more resources in the patent examination process. The rise in the number of patent applications is putting pressures on the time to accomplish patent examination. Most likely, these pressures lead to greater leniency because rejecting a claim is harder and more time consuming than accepting it.

Policies that call for an optimal degree of patent protection may then suffer from pressures in the patent examination process. Data and proper research designs may address this question – that is, they may study and test whether different aspects of the patent examination process affect the nature and implications of patents, and the extent to which we can implement managerial practices with socially desirable implications for the classical trade-off of patents or their social functions.

6. CONCLUSIONS

This article has shown that patents have many functions and play many roles in modern societies. On the one hand, their classical function is to provide exclusion rights to the owners of inventions in order to appropriate the returns from investments in easy-to-imitate intellectual outcomes. This social pact, whereby society offers exclusion rights to support the incentives to innovate, has been the subject of long debates. While society accepts the rationale of this pact, the exact details and the extent to which patents provide this protection has raised discussions. Society sometimes worries that too much monopolization of knowledge, especially when it adds to extant market power, can lead to excessive concentration and too limited diffusion of knowledge and innovation.

On the other hand, patents perform other functions in our societies, which we highlight in this article. All these functions have wider positive implications for society. This squares with the fact that smaller high-growth firms are increasingly vehicles of innovation and growth, and they benefit to a greater extent from the fact that patents signal their value, disclose information, and encourage markets for technology (e.g. EUIPO, 2019b).

The gist of this article is that we need to understand better both the private and social functions of patents. There are simply too many effects triggered by each one of these functions to be able to disentangle the overall positive or negative effect of patents. A better approach is to understand the general directions that we can take to favor the more beneficial social functions of patents – whether in relation to the private incentives to inventions or the broader social effects discussed in this article.

Discussing policies to achieve these goals is beyond the extent of this article. However, we have noted that providing detailed evidence about the nature and implications of patents is critical pre-condition for good policies and management practices about patents. While patent data are abundant, we are still in a world in which these data are not collected to produce evidence about relevant questions. This leaves important questions unanswered.

In particular, this article suggests that Patent Agencies, stakeholders and other relevant institutions provide relevant questions, and create the conditions to collect data or to run field experiments that allow for causal identification of mechanisms. This is crucial to make policy or managerial decisions that depend on the deployment of these mechanisms.

It is probably now time to abandon the "high-level" debate on whether patents are good or bad. We can do much better by implementing serious and systematic evidence-based managerial and policy actions. To do so, society needs the collaboration of the Agencies, institutions, stakeholders, and policy-makers that can help to set the questions and collect the right data to understand the deeper mechanisms that address these questions.

References

Arora, A. (1995) "Licensing Tacit Knowledge: Intellectual Property Rights and the Market for Know-How" *Economics of Innovation and New Technology*, 4, 41-95

Arora, A. and Ceccagnoli, M. (2006) "Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing" *Management Science*, 52 (2), 293-308

Arora, A., Ceccagnoli, M. and Cohen, W. (2008) "R&D and the Patent Premium" *International Journal of Industrial Organization*, 26 (5), 1153-1179

Arora, A., Fosfuri, A. and Gambardella, A. (2001) *Markets for Technology: The Economics of Innovation and Corporate Strategy*, The MIT Press, Cambridge MA

Arora, A., Gambardella, A., Magazzini, L. and Pammolli, F. (2009) "A Breadth of Fresh Air? Firm Type, Scale, Scope and Selection Effects in Drug Development" *Management Science*, 55 (10), 1638-1653

Arrow, K. (1962) "Economic Welfare and the Allocation of Resources for Invention" in Groves, H. (ed.) *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton University Press, Princeton

Athreye, S. and Cantwell, J. (2007) "Creating Competition?: Globalisation and the Emergence of New Technology Producers" *Research Policy*, 36 (2), 209-226

Bell, A., Chetty, R., Jaravel, X., Petkova, N. and Van Reenen, J. (2019) "Who Becomes an Invntor in America? The Importance of Exposure to Innovation" *Quarterly Journal of Economics*, 134 (2), 674-713.

Bhaskarabhatla, A., Cabral, L., Hegde, D. and Peeters, T. (2021) "Are Inventors or Firms the Engine of Innovation?" *Management Science*, forthcoming

Bloom, N., Schankerman, M. and Van Reenen, J. (2013) "Identifying Technological Spillovers and Product Market Rivalry," *Econometrica*, 81 (4), 1347-1393

Bloom, N., Jones, C., Van Reenen, J. and Webb, M. (2020) "Are Ideas Getting Harder to Find?" *American Economic Review*, 110 (4), 1104–1144

Choudhury, P., Starr, E. and Agarwal, R. (2020) "Machine Learning and Human Capital Complementarities: Experimental Evidence on Bias Mitigation" *Strategic Management Journal*, 41 (8), 1381-1411

Cohen, W., Goto, A., Nagata, A., Nelson, R. and Walsh, J. (2002) "R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States" *Research Policy*, 31 (8), 1349-1367

Conti, R., Gambardella, A. and Novelli, E. (2019) "Specializing in Generality: Firm Strategies When Intermediate Factor Markets Work" *Organization Science*, 30 (1), 126-150 (*open access* https://pubsonline.informs.org/doi/pdf/10.1287/orsc.2018.1243)

Corsino, M., Mariani, M and Torrisi, S. (2019) "Firm Strategic Behavior and the Measurement of Knowledge Flowswith Patent Citations" Strategic Management Journal, 40 (7), 1040-1069

European Union Intellectual Property Office (EUIPO) (2019a) "IPR-Intensive Industries and Economic Performance in the European Union" Report, September, https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/IPContributionStudy/IPR-intensive_industries_and_economicin_EU/WEB_IPR_intensive_Report_2019.pdf

European Union Intellectual Property Office (EUIPO) (2019b) "High-Growth Firms and Intellectual Property Rights" Report, May, https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/reports/2019_High-growth_firms_and_intellectual_property_rights/2019_High-growth_firms_and_intellectual_property_rights.pdf

European Union Intellectual Property Office (EUIPO) (2021) "IPR and Firm Performance in the European Union" Report, February, https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/reports/IPContributionStudy/IPR_firm_performance_in_EU/2021_IP_Rights_and_firm_performance_in_the_EU_en.pdf

Farré Mensa, J., Hegde, D. and Ljungqvist, A. (2020) "What is a Patent Worth? Evidence from the U.S. Patent 'Lottery'" *Journal of Finance*, 75 (2), 639-682

Fromer, J. (2009) "Patent Disclosure" *Iowa Law Review*, 94, 539-606

Furman, J., Nagler, M. and Watzinger, M. (2021) "Disclosure and Subsequent Innovation: Evidence from the Patent Depository Library Program" *American Economic Journal – Economic Policy*, forthcoming

Galasso, A., Schankerman, M. and Serrano, C. (2013) "Trading and Enforcing Patent Rights" *Rand Journal of Economics*, 44 (2), 275-312

Galasso, A. and Schankerman, M. (2015) "Patents and Cumulative Innovations: Evidence from the Courts" *Quarterly Journal of Economics*, 130 (1), 317-369

Gambardella, A. and McGahan, A. (2010) "Business-Model Innovation, General Purpose Technologies, Specialization and Industry Change" *Long Range Planning*, 43, 262-271

Gambardella, A., Harhoff, D. and Varpsagen, B. (2017) "The Economic Value of Patent Portfolios" *Journal of Economics and Management Strategy*, 26 (4), 735-756

Gambardella, A., Harhoff, D. and Verspagen, B. (2008) "The Value of European Patent" *European Management Review*, 5 (2), 69-84

Gambardella, A., Heaton, S., Novelli, E. and Teece, D. (2021) "Profiting from Enabling Technologies?" *Strategy Science*, 6 (1), 75-90

Gans, J., Hsu, D. and Stern, S. (2002) "When Does Start Up Innovation Raise the Gale of Creative Destruction" *Rand Journal of Economics*, 33 (4), 571-586

Gans, J., Hsu, D. and Stern, S. (2008) "The Impact of Uncertain Intellectual Property Rights on the Market for Ideas: Evidence from Patent Grant Delays" *Management Science*, 54 (5), 982-997

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., Harhoff, D., Hoisl, K., Lebas, C., Luzzi, A., Magazzini, L., Nesta, L., Nomaler, O., Palomeras, N., Patel, P., Romanelli, M. and Verspagen, B. (2007) "Inventors and Invention Processes in Europe. Results from the PatVal-EU Survey" *Research Policy*, 36 (8), 1107-1127

Graham, S., Marco, A. and Myers, A. (2018) "Patent Transactions in the Marketplace: Lessons from the USPTO Patent Assignment Dataset" *Journal of Economics and Management Strategy*, 27 (3), 343-371

Gross. D. (2019) "The Consequences of Invention Secrecy: Evidence from the USPTO Patent Secrecy Program in World War II" Working Paper.

Hegde, D., Herkenhoff, K. and Zhu, C. (2020) "Patent Publication and Innovation" https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3158031

Hegde, D. and Luo, H. (2018) "Patent Publication and the Market for Ideas" *Management Science*, 64 (2), 652-672

Higham, K., de Rassenfosse, G. and Jaffe, A. (2020) "Patent Quality: Towards a Systematic Framework for Analysis and Measurement" https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3697223

Hochberg, Y., Serrano, C. and Ziedonis, R. (2018) "Patent Collateral, Investor Commitment, and the Market for Venture Lending" *Journal of Financial Economics*, 130 (1), 74-94

Holmstrom, B. (1989) "Agency Costs and Innovation" *Journal of Economic Behavior and Organization*, 12 (3), 305-327

Hall, B. and Ziedonis, H. (2001) "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995" *Rand Journal of Economics*, 32 (1), 101-128

Hsu, D. and Ziedonis, R. (2013) "Resources as Dual Sources of Advantage: Implications for Valuing Entrepreneurial-Firm Patents" *Strategic Management Journal*, 34 (7), 761-781

Hsu, P-H., Lee, D., Tambe, P. and Hsu, D. (2020) "Deep Learning, Text, and Patent Valuation" https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3758388.

Kline, P., Petkova, N., Williams, H. and Zidar, O. (2019) "Who Profits from Patents? Rent-Sharing at Innovative Firms" *Quarterly Journal of Economics*, 134, 1343-1404

Kogan, L., Papanikolaou, D., Seru, A. and Stoffman, N. (2017) "Technological Innovation, Resource Allocation, and Growth" *Quarterly Journal of Economics*, 132, 665–712.

Luca, M. and Bazerman, M. (2020) *The Power of Experiments*, MIT Press.

Merges, R. and Nelson, R. (1990) “On the Complex Economics of Patent Scope” *Columbia Law Review*, 90 (4), 839-916.

Ohlhausen, M. (2016) “Patent Rights in a Climate of Intellectual Property Rights Skepticism” *Harvard Journal of Law and Technology*, 30 (1), 1-51

Office for Harmonization in the Internal Market (OHIM) (2015) “Intellectual Property Rights and Firm Performance in Europe: An Economic Analysis” Report, June, https://euipo.europa.eu/ohimportal/documents/11370/80606/Intellectual+property+rights+and+firm+performance+in+Europe

Sampat, B. and Williams, H. (2019) “How Do Patents Affect Follow-on Innovation? Evidence from the Human Genome” *American Economic Review*, 109 (1), 203-236:

Schankerman, M. (1998) “How Valuable is Patent Protection? Estimates by Technology Field” *Rand Journal of Economics*, 29 (1), 77-107

Teece, D. (1986) “Profiting from Technological Innovation” *Research Policy*, 15, 285-305

Teece, D. (1988) “Technological Change and the Nature of the Firm” in Dosi, G. et al. (eds.) *Technological Change and Economic Theory*, Printer Publishers, London, 257-281

Torrisi, S., Gambardella, A., Giuri, P., Harhoff, D., Hoisl, K. and Mariani, M. (2016) “Using, Blocking, and Sleeping Patents: Empirical Evidence from a Large Inventor Survey” *Research Policy*, 47 (7), 1374-1385

Williams, H. (2017) “How Do Patents Affect Research Investments?” *Annual Review of Economics*, 9, 441-469

World Intellectual Property Organization (WIPO), *various years*, “IP Facts and Figures” https://www.wipo.int/publications/en/series/index.jsp?id=36

Ziedonis, R. (2004) “Don’t Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms” *Management Science*, 50 (6), 804-820