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How valuable is a firm's patent? A New approach from Patent Citations Data

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How valuable is a firm's patent?

A New approach from Patent Citations Data

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Abstract:

Intellectual Property Protection serves two purposes. The first is to encourage innovation by granting patent holders monopoly rights to their inventions for fixed periods of time. The second is to speed up innovation by allowing patent holders to license their inventions and obtain royalties. While few doubt the economic benefit of the system and its ability to foster innovation, empirically assessing the value of a patent to a firm has proved exceptionally difficult. Important in its own right, the question is even more important for developing and improving patent policy.

This paper uses patent citations as a measure of patent value in an attempt to quantify the impact patents have on a firm's value. Patent citations both reflect the vast heterogeneity in patent value and capture the breadth of the patent by observing the number of areas in which it is later cited. As such, they provide a more direct measurement of patent value. Results find however, that all these variables are statistically insignificantly different from zero, and a discussion of potential explanations is given. At the very least, the relationship between number of citations received by a particular patent and its impact on firm value is proven far more complex than suggested by the previous literature, suggesting the need for further research.

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Section I: Introduction

A patent provides a government sanctioned monopoly for a set period of time, usually twenty years, subject to the payment of maintenance fees. Patent holders are encouraged by the potential supranormal profits, hence the considerable effort by many to develop new products. From society's perspective, four rationales exist to tolerate the efficiency cost imposed by such monopolies: (1) patents encourage innovation, (2) patents encourage the disclosure of that invention once made, (3) patents enable companies to invest enough to produce and commercialize the product, and (4) patents encourage further innovation in areas of societal interest (Mazzoleni and Nelson 1998). The vast majority of patents, about 80% (Hall et al. 2001), are in the hands of corporations (as opposed to individuals). Clearly firms must derive benefit from holding these patents and the monopoly rights that come with the patents. But how much? Patent values vary dramatically, and evaluations of patent prices necessitate expert patent attorneys and valuation teams,¹ an expensive and time-consuming affair. Even so, results are not guaranteed. Indeed, even companies providing patent valuation services acknowledge that their models may not reflect the value of the patent since this value "cannot be quantified by conventional valuation theories, such as sales value or licensing value".²

It is important to determine a quick and relatively accurate measure of the value of a patent. As production can be outsourced to the lowest cost producer anywhere in the world, from the point of view of the firm, intellectual property is increasingly valuable relative to the physical production of individual products. To give but one example, most of the value in the ipod is paid

¹ See "Steps for Pricing a Patent"

<http://www.journalofaccountancy.com/Issues/2004/Nov/20StepsForPricingAPatent.htm>

² Patent Value Predictor website: <http://www.patentvaluepredictor.com/FAQs.asp>

to Apple for the originality of the concept, rather than to the multiple manufacturers who complete the manual work.³ From the perspective of society, the private benefit earned by firms need to be determined in order to contrast it with social costs and come up with patent optimizing policies.

Early work in this topic focused on the theoretical aspects, concerned with developing models of “optimal patent length and breadth”, with empirical studies hindered by the lack of available data. Indeed, the few studies that used patent data (Schmookler [1966], and Griliches [1990]) were limited to simple patent counts. This has recently changed, with more detailed and better organized patent information made available online. This rich new information source enabled Hall et al. to use patent citations data to proxy patent value. While an obvious improvement on previous work, they do not adjust their measure of patents for the scope of the patent, and the number of previous inventions a patent is based upon. This paper endeavors to improve the existing literature on patent valuation by explicitly incorporating these two factors.

The remainder of the paper is organized as follows: Section II presents the literature review. Section III discusses the theory behind my conceptual model and presents the ideal data. Section IV describes the actual data and highlights some of the limitations it places on the study. Section V presents and explains the general model and results. Section VI concludes.

³ “An Ipod has global value. Ask the (many) countries that make it”. The New York Times, 28 June 2007 <http://www.nytimes.com/2007/06/28/business/worldbusiness/28scene.html>

Section II: Literature Review

2.1 Basic Theory

The early patent literature focuses on maximizing the dynamic benefits of innovation while taking into account the static costs brought by monopoly power to welfare. The ‘canonical’ approach dates back to the work of W. D. Nordhaus [1967] and Scherer [1972], and focuses on the value of patents to increase innovation. It is assumed that the inventors are working on different, non-competing creations, and therefore stronger patent protection improves the incentives to invest in research and development, providing more monopoly rents. By contrast, later literature, exemplified by Klemperer [1990], and Gilbert and Shapiro [1990], assumes that imitation is costless, and thus always a threat to the first innovator. In this tradition, patents are more valued as tools encourage disclosure. In his model of the trade-off between patent length and breadth, Klemperer considers the problem in a model of spatial product differentiation: a larger patent breadth corresponds to a larger region in the product space being included in the patent (scope), and hence is more valuable to the firm. Gilbert and Shapiro, on the other hand, emphasize the social cost aspect: the extent of substitution away from the patented product, and its associated deadweight loss, will rise as patents become “broader”. They conclude that in a homogeneous product model, long-lived but narrow patents are socially optimal, as narrow definitions allows for more inventors to be rewarded. In both cases however, inventions are treated as discrete actions while innovation is increasingly cumulative.

Scotchmer [1991], and Gallini [1992] identify the problem created by treating inventions as discrete rather than as a cumulative process: patents have externalities and spillovers, so it becomes difficult to optimally reward both early and later innovators for their contributions:

temporal issues add another dimension to the trade-off between length and breadth. More directly to the point of this paper, this changes the value of patents to firms, as they have to contend with the additional issue that a longer patent may create the incentive for rivals to “invent around” the patent, thereby decreasing its usefulness to the firm. Such theoretical debates however, cannot be resolved without an empirical estimation of patent value and its impact on firms.

2.2 Empirical Work

The key empirical question hinges upon estimating the value of each patent. Using surveys to the holders of about 2% of the patents granted in 1938, 1948, and 1952, Sanders, Rossman and Harris [1958] find that 75% of the patents were reported to have economic value to assignees. More specifically, they find that 57% of the patents were used or about to be used in the firm’s primary industry and another 11% having had or expected to have other benefits. Surveys helps us to better understand the opinion of firms on how useful their patents are, and manages to gain such insight in an era when patent data were scarce. This approach, however, does not consider either the costs of patents to firms such as renewal costs, or time spent on application or in defending them from litigation. Nor, for that matter, does it give a quantitative measure of the actual patent value.

One of the main problems in attempting to quantify the value of a patent is the implicit nature of many of the costs and benefits. Indeed, a large body of literature focuses simply on the question of “how to develop the appropriate proxies” rather than the central question of how to estimate the value itself. For example, a firm needs to take into account potential litigation costs arising from infringement: how much is the firm willing to spend to defend its patents? Having

more patents could either decrease the costs of litigation, with the other firms are afraid of infringing, or in contrast increase the risk of litigation, with the firm has to protect more patents. Lanjow and Schankerman [2001] show that such implicit costs are not easily incorporated into a model. In addition, as Bessen and Meurer [2005] show, litigation also brings strong disincentives for private individuals to litigate against larger firms, firms with more patents. Patents thus serve additional functions, whose values may not be reflected in an economic model.

How then, should we take all these factors into consideration when valuing a firm's stock of patents? The increased availability of patent data, exemplified recently by the work of Hall et al. [2001], [2005], may help answer this question. With all the relevant information on the invention and the person to which it is assigned now put on record upon the granting of a patent, detailed patent data is now available.

This is not to say that no previous work was done on patent data. Scherer [1965] manually classifies a sample of 15,000 patents into "industry of origin" and "industries of use", plotting a detailed technology flow of the degree to which innovation is promoted in different areas by the presence of a patent. Schmookler [1965] maps patent counts to specific industries, focusing on determining the inter-industrial similarities and differences. Finally, Griliches [1990] matches patents to external stock market measures of firms' value using Compustat data. All three of these authors recognize the potential usefulness of patent data in helping estimate patent value and control for industrial differences. At the time however, the only widely available patent data was a simple patent count. They are thus unable to capture the variation in patents' technical and economic importance, as demonstrated by Pakes and Schankerman [1987]. Using data from the U.K, France, and Germany, these authors use renewal cost schedules as a measure for patent value, arguing that the patent holder's willingness to pay for extensions is better

indication of patent value. This measure however, does not take into account new patents filed, although they obviously are also part of the firm's stock of knowledge. Clearly, the value of both older and new patents should be taken into account when considering the sum of patent values within a firm.

Patent citations provide a potential solution. First, they delimit the scope of property rights awarded by each new patent, and enable the tracing of spillovers from inventions: Patent B has to cite patent A if it employs knowledge previously patented by A. Legally, it will have to pay for the privilege of using that information, reducing its value and increasing the value of patent A. Citations are thus a fairly direct indicator of the "importance" of individual patents, with the variation in patent value reflected in the varying number of citations. Additionally, citations are also indicative of the *ex-post* value of the innovations disclosed. Trajtenberg [1990] demonstrates the close association between citation-based patent indices and measures of the value of innovation in the case of Computed Tomography scanners, results validated and broadened by Hall et al. [2005]'s analysis of a variety of patents. While the Hall et al. work represents an important advancement in this literature the authors do ignore two key factors affecting patent value: the scope, and the number of citations made by the patent to previous patents.

This paper examines the importance of these two variables in addition to the number of citations received as indicative of patent value. For example, a broader patent, one that has applications in more technological fields is expected to have a positive impact on firm value as the firm may earn profit from licensing out its patents to other firms. In terms of number of citations given, a patent could be more valuable if it is based on a large number of previous patents, or alternatively it can be more valuable because it is very innovative, based on few

patents. It is hoped that this paper will contribute to the literature on patent valuation and shed new light on the more fundamental questions of benefits and costs of patents.

III. Conceptual Model: Theory and Ideal Data

3.1 Modeling Firm Behavior

Firms will want to maximize the value of their company, and can choose to invest in physical capital, human capital (such as improving the education and skills of its workforce), or invest in knowledge capital represented by patent holding. The third option is attractive: investing in human capital is risky as employees might leave the company, while patents are held by the firm until and unless it wishes to sell it, patents provide a basically assured stream of revenue. Upfront costs however, are high, so for a firm to be willing to engage in such activity, the long-run revenue should be maximized, and costs minimized. Figure 1 illustrates the issue. In the beginning, the firm has to incur a large cost as it invests in developing a new product; later, as the firm becomes more proficient, costs are lower as they consist mostly of fabrication and patent application costs. As the firm obtains a patent, the savings and earnings of the firm increase. Eventually, the patent expires, and savings decrease until the patented invention is fully obsolete or perfect competition drives profits to zero.

Under the assumption that a firm engages in patenting, a simple profit-maximizing model (Figure 2) summarizes the tradeoff between “quantity” and “price” (or quality). The value of the stock of knowledge held by the firm depends on both the quantity of patents held as well as the “price” or the value associated with the patents. The profit from a firm’s knowledge stocks will be the product of the two parameters, and firms will seek to find the balance between the number

and “quality” of patents maximizing benefits. The important question then becomes “how does the firm ‘choose’ these parameters”? Time horizon may play a role in this: firms may not know how valuable a patent will be when filing but gain more knowledge through time, and potentially increasing the weight they place on quality over quantity. One criticism of this theory is that firms do not actually behave in this way, as the difficulty of estimating patent “quality” is the very reason why there is continuing research in this area. However, even if this may be the case, this does not affect my estimation of firm value using patent data. Indeed, it may explain the persisting rapid increase in patenting despite the potentially low value of most of these patents. A more critical issue is the fact that innovation is a dynamic process as modeled in Kamien and Schwartz (1982), but lack of time constrains my results to the static model. Interesting observations however, can be reached even under the static model.

3.2 Modeling Firm Value

Following the work of Trajtenberg [1990] and Hall et al. [2005], patent citations can be matched to the stock market value of a firm. Yet the value of each patent is not only based upon the number of citations it receives, but also affected by its scope and the number of citations it makes to previous patents. In terms of scope, a broader patent is expected to have a positive impact on firm value, as the firm may earn profit from licensing out its patents to other firms. The signs on number of citations made and received are more ambiguous. A patent could be more valuable because it is innovative and thus able to capture all the revenue from developing a product, or on the contrary be more valuable through being based on a wide number of patents. Generally, I hypothesize that patents based on a large number of other patents as measured by the number of citations reduces the value of a patent, while receiving citations is a positive

indicator of the patent value. Finally, patent length is another parameter affecting patent value, but with the data coming from one country and one year, length is taken as constant. The basic estimating equation for the model is thus:

$$(1): y = B0 + B1 X1 + B2 X2 + B3 X3$$

Where y is equal to firm value, X1 is the scope of the firm, X2 is the number of citations a firm's patents give, and X3 the number of citations the firm receives.

IV. Summary Statistics

4.1 Dataset and Limitations

The dataset merges two sets of variables. The first comes from NBER and the work of Hall et al [2001], and contains all the patents granted by the United States Patent and Trademark Office (USPTO) during the period January 1 through December 30, 1996. Patents are then matched with the firms that own them through matching assignee codes with specific firms. Patent entries were checked manually, deleting all the patents for which stock market data were missing (for example, patents owned by foreign firms or private firms). The results were then combined with the stock market measurement of firm value, as measured by the Wall Street Journal's February 2002 Shareholder scoreboard⁴. Two measures are of employed from this dataset: the average five-year return in percentages, and its relative surplus/deficit to other firms in the industry. Ultimately, the data set contains 19093 patents owned by 216 different U.S. firms. 1996 was selected because it was far enough away from the end of the NBER dataset to avoid the major truncation problems at the end of that dataset (1998, 1999). A 5-year period then gives patents enough time to accumulate citations, leading to a 2001 estimation of firm value.

⁴ Wall Street Journal Shareholder Scoreboard, February 25, 2002. Sources: Rankings are by L.E.K. Consulting LLC, based on data from Dow Jones &co; Media General Financial Services, a unit of Media General Inc., and Tradeline.com, a unit of Platinum Equity LLC.

Variables in the final dataset are summarized in table 1. The proxy for patent scope is the number of claims in different technological areas that the patent citations appear in. The firm's scope is more problematic. While it is true that it could be proxied by a simple summation of the scope of individual patents (absolute scope), it is not ideal as claims could be repeated when summing across patents, and a simple number count does not reflect this. To decrease this error, the average scope of the patents could be used. Ideally of course, scope of the firm would be a summation of the individual scopes, taking into account duplicates. A more accurate measure would be to use the number of categories under the SIC codes, but the lack of data and time does not allow for this in the present study. Ideally, it would be possible to match the impact of the scope of each patent on firm value, but we are unable to disaggregate the data to that level. The other two variables, "numbers of citations made and given for individual patents" are directly summed to get firm level data. One obvious potential problem is selection bias, leading to bias in the relationship between patent citations and stock market performance, but it is unavoidable due to the absence of such data for private firms for example. Also, it would be ideal if the study replicated the work by Hall et al. and simply added measures for the missing variables, but because the patents were not matched individually to firms, this is also something we are unable to do.

4.2 Summary Statistics

An examination of the dataset, through a historical lens, as Hall et al. [2005] is helpful. To give one example, they were able to conclude that the area of Computers and Communication has received a rapidly increasing average number of citations, from the lowest position in 1965 to the highest in 1975. While the trends are fascinating, they are not the focus of this paper, and

are not included here.

Summary statistics are given in Table 2. Although variations are large for all variables in the dataset, it is possible to note some important facts. First, on average, a patent is usually cited about 30 times as more than the number of patents on which it is based. That this ratio is positive, suggests that firms do bring innovation in their patents, and do not just “patent for the sake of patenting”. In absolute terms, firms have grown in value, albeit only an average of 1.14% per year over 5 years. The fact that the relative growth value is negative however, suggests that other, smaller firms, with hypothetically fewer patents, may have done better than the large firms with numerous patents. This would bring doubt to the hypothesis that patents are used just for their economic value bringing royalties, but rather they may be used for other reasons. Most importantly, there are large standard deviations compared to the means for each variable, a high variation across all areas making these statistics hard to interpret directly.

V. Analysis

5.1 Estimating Equation

The estimating equation, rephrased slightly, is:

$$\begin{aligned} (2) \text{ Firm Value} &= f(\sum \text{ Patent Value}) \\ &= \alpha + \beta_1(\text{Patent Scope}) + \beta_2(\text{Citations Given by Firm}) + \beta_3(\text{Citations Received by Firm}) \end{aligned}$$

Where firm value is either the average 5-year return or the relative surplus/deficit compared to the industry. For scope, as argued previously, average patent scope seems to be a more logical choice. The scope is thus proxied by the average number of claims patents owned by the firm. Number of citations given and number of citations received by the firm are simple summations

of the same variables for individual patents.

5.2 Results and Analysis:

The basic model is run on both absolute and relative values of firm return, with results fairly similar for the two cases. Analysis however, must be cautious since no variables are actually significant even at the 10% level (with the exception of scope in the absolute firm value model). In effect, there are no results statistically different from zero. That is not too surprising, as average returns to shareholders and other measures of firm value are much more likely to be affected by short-term business conditions such as losses and other more direct measures of the firm's well being instead. The values of knowledge stocks, results suggest, are not as well reflected in measures of firm value. Of course, if this is indeed the truth, then trying to model firm and patent value through citations may not hold, unlike what the limited preceding empirical literature has argued and potentially new approaches will have to be sought out. It is also possible, as will be explained in more detail later, that this low significance could be due to the limited nature of the data, restricted as it is to only 216 of the largest public firms; or because the firms that own the patents are not the ones who actually use and truly benefit from the patent. Yet another explanation would be that patents and citations are used not just for their economic value, but also for other reasons the model is unable to account for, creating issues of omitted variable bias. All these will be discussed in detail later in the paper.

That being said, we should still take a look at the results, summarized in Tables 3 and 4. In the absolute return case, scope has a positive value of 0.002281, and an impact of 0.105555 in the relative return case. In both situations, it is in accord with theory. More interesting is the fact that it is so much more positive for the relative value of the firm. This difference is likely to be

explained when we also take a look at the constants: in the absolute firm value situation, the constant is a relatively large positive number, while it is a large negative in the case of the relative firm value. It is thus not surprising that the positive impact associated with having a broader scope will be more evident under a situation where overall the negative impact is more dominant. This is reflected in comparing the significance of the variable across the models, with a t- statistic of 0.02 in the absolute value situation, and a t-statistic of 0.95 in the relative value case. Indeed, the standard error on this coefficient in the absolute case is orders of magnitude larger than the coefficient whereas the standard error, albeit large, is smaller than the coefficient in the relative value case.

Turning next to the number of citations made, the coefficients are negative in both cases (-0.0004112 compared to -0.000175). This suggests that the effect of making additional citations, taking away royalties paid to use someone else's patent, dominates the value that is gained from cumulative innovation. Indeed, as I learned through informal discussions with patent lawyers, they advocate clients to not patent inventions needing to make many citations, as the lack of innovation may make it more vulnerable to litigation attacks.

What is interesting is that the number of citations a firm receives is also negatively related to the firm value in both situations (-0.000016 compared to -0.000053). It is true that results are not significant and that the overall impact of this variable in light of the other two is extremely small (about twice as small as the impact of citations given and two thousand times as small as the impact of scope in both situations). This result could also be a result of selecting a poor proxy for scope. Taking the results as they are however, it is possible that more citations do not bring as much benefit as not disclosing the innovation and keeping a trade secret would. This is a troubling sign when the whole rationale of having patents is to encourage disclosure of what

would otherwise be kept secret, and suggests that potentially, the benefits of patents are not large enough. This negative relationship is indeed repeated even when running firm value on just the number of citations received, as summarized in Tables 7 and 8.

Comparing the relative impacts of the variables through elasticities (Table 5 and 6) scope has a larger impact than citations made when using the relative measure of firm value, while the opposite is true when using the absolute measure of firm value. Finally, in the original model, the constant is positive in the case of the absolute value, but negative in the case of relative value. This suggests that even though overall the firms have grown, smaller firms in the industry, firms with likely fewer patents, have outperformed them. Yet many firms still hold many patents despite the seemingly negative impact on value, suggesting that patents are not necessarily used for their economic value in bringing royalties, but potentially for other purposes. For example, as complementary literature from political science has often pointed out, firms may engage in defensive patenting, with patents providing protection against infringements. In an era of increased litigation, it is a worthwhile benefit, but whose value cannot be included in citations data. Alternatively, another potential explanation for the low level of correspondence between the variables and firm value could be due to the fact that patents do not necessarily benefit the firms that they are assigned to, but rather the firms that own them. Using a recent example, the pharmaceutical company Myriad Genetics derives revenue from leasing two patents on the BRCA1 and BRCA2 genes, but the actual owner of the patents is listed as the University of Utah Research Foundation⁵.

⁵ Hamblett, Mark. "Genes Linked to Breast, Ovarian Cancers Are Ruled Unpatentable" *New York Law Journal*. March 30, 2010. Accessible at: http://www.law.com/jsp/article.jsp?id=1202447064274&Genes_Linked_to_Breast_Ovarian_Cancers_Are_Ruled_Unpatentable

Going back to the data, comparing the fitted versus actual values (Figures 3 and 4), the relative value model is a much better predictor of actual firm values. It seems thus more important to compare how firms fared in relation to other firms in the industries more than their absolute returns. This makes sense, as a firm that does poorly in general may still be the best one in its area, while a firm with good returns may still overall be less valuable as it lags behind its competitors. This is the dimension most firms consider in any case: there is no reason for a firm in pharmaceuticals to compare themselves to a chip-making company. Echoing the work of Scherer and Schmookler, this fact also encourages us to next look at the inter-technological differences as a potential explanation for the results. These differences are indeed also reflected in the residual plots (Figure 5 and 6), with the largest scope firms in areas such as chemicals and electronics. Finally, while there are no violations of the classical assumptions, with a Breusch-Pagan test yielding chi-square values of 1.72 and 0.41 compared to the critical value of 6.25, and a VIF test for multicollinearity giving a highest and average value of 1.01, the model still should be changed. Hopefully, this will also increase the significance of the results.

Inter-technological Comparison

The firms under investigation, being large public-held companies, often have patents in multiple technological categories. As defined by Hall et al. [2001], 6 main categories exist, and patents may well be used differently from one to the other. The categories are: Chemical (excluding drugs); Computers and Communication (C&C); Drugs and Medical (D&M); Electrical and Electronics (E&E); Mechanical (M); and Others. We then run a simple regression of the number citations disaggregated by category on both absolute and relative measures of firm value. Results however, remain highly insignificant, which does not enable us to make any

conclusions as to the relative impact of the variables. Clearly, the problems previously mentioned in attempting to measure firm value through patent data are not overcome in anyway by this disaggregation. That being said, some observations may still be hazarded.

Results are summarized in Table 7 and 8. First, a look at the absolute results: having an additional citation does have a small positive effect, as expected by theory, in areas such as Computers and Communication (category 2), Drugs and Medical (category 3), and Others (category 6). The negative impact is only seen in the other three areas. Results in the relative value model on the other hand, have patent citations in categories 1 and 6 associated with higher firm value. Combining the results, we see that holding patent citations from categories 1, 2, 3 and 6 may be easily seen as positive or negative depending on which measure of firm value is looked at, thus potentially explaining the fact that they build up the number of patents and patent citations they hold. More patent citations in Electrical and Electronics (category 4), and Mechanical (category 5), however, are correlated with lower firm values in both situations.

Even if we do ignore the low significance of results, these results could simply be a result of different business conditions for the two groups over the same time period, and those firms happened to have done poorly, or that patents in these categories use citations differently. In any case, the lack of significant results further hinders our ability to interpret results. While we can say that the models do not suffer from problems of heteroskedasticity or multicollinearity, we cannot conclude that either variable is useful in determining patent and firm value, at least the way we measured it. This is disappointing, but as stated previously, this is unsurprising due to the numerous problems present with the data and models.

In addition to the previously stated problems, the data is further limited since it includes only 216 of the 1000 largest publicly traded firms in the United States in the year 2001. Many

smaller public firms, as well as private and foreign firms, are not included in the dataset, further weakening the robustness of the results. Yet the firms present dramatic variations in how well they did over this time period. It is thus likely that even with a larger and more diverse sample, results would not change, though they may become more significant. In addition, the problem of finding a good proxy for both patent and firm scope may also affect the validity of the results. With more time, an investigation into the number of product categories (measured by SIC codes) each firm owns would probably be a better measure for scope. An additional consideration is the validity of using a static model in a dynamic process such as innovation. With more time the study ought to be repeated using Kamien and Schwartz's 1982 dynamic model, yielding potentially different results. These would be worthwhile avenues to further pursue, but lack of time constrains my results to the static model. We are able to conclude however, that the relationship between patent citations, patent value and firm value is much more complex than the limited empirical work so far have concluded, suggesting the need for extensive further research. Finally, in terms of methodology, even if the results were significant, the approach is only able to estimate the value of past patents, looking back retroactively. It would not be able to measure the value of a new patent, which the firm may wish to get an estimate for when coming up with the invention.

VI. Conclusion

Ultimately, this study argues that we cannot conclude that either number of citations given or received by a patent, nor its scope, is significant in contributing to the value of the patent as reflected through firm value. While this seems to be in opposition with the theory and the previous limited empirical works however, a number of potential explanations were advanced. At the same time, however insignificant, it was heartening to see that patent scope and

number of citations made did have the expected signs. Potentially, this relationship would be further confirmed with increased data. Certainly more research will be needed to explain the puzzling relationship observed between firm value and the number of citations received, even if it too is statistically insignificant. This potentially does reflect the reality of the relationship: in the real world, many patent thickets exist. Perhaps more care in choosing inventions to patent would make number of citations more indicative of the patent value, and through it, firm value. Further evidence for this is gained from the observation that the relative firm value is consistently estimated to be negative. Most firms in the dataset have done poorly compared to the industry despite being the largest and biggest patent owners, potentially as patent owners are not the ones who are necessarily using the patent. A mapping of the latter would probably also help raise the significance of the results. Overall, the limited results provide evidence of a complex relationship between patents, citations and firm value, one that needs to be investigated in more detail before we can conclude whether “more patent citations unambiguously mean a higher patent and firm value”, as argued by Hall et al.

Similar ideas are echoed when looking at the difference between industries, for while results were not significantly difference across technological categories; there are still trends that could be significant. Computers and Communication and Drugs and Medicines for example, are areas where cumulative innovation is potentially more beneficial in terms of absolute average returns to shareholders. Results differ somewhat if cast in terms of relative firm value: in that case, holding increased number of citations in the area of chemicals is associated with a higher relative value. While the mixed nature of the results and their relative insignificance suggests that more work needs to be done before conclusions can be reached, it remains that firms ought to consider more carefully how they use patents and patent citations, for example firms with

patents in Electrical and Electronics (category 4), and Mechanical (category 5). On a broader level, the inter-industry differences should be understood to investigate more fundamental questions as to the overall benefits and costs of patents to society as well as to firms. If firms are not using the patents appropriately and not earning revenue as predicted, it is likely that the balance between firm benefits and social cost is also not the appropriate one. Further attempts at patent optimization will need to solve the issues here raised before significant progress can be made in that area. The topic of patents is a broad one, spanning many questions of societal interest, but basic empirical questions need to be resolved before these can be answered. As the paper points out, this is far from being the case.

Ultimately though, even if we accept the results despite the low significance, the whole analysis hinges upon assuming that the value of a patent lies in its ability to earn royalty revenue by having others pay for it, not in its other characteristics such as prevention of litigation. This is a literature that remains lacking in economical research, but has developed in the political science and legal studies realms, with the problem how to include those more implicit costs in economic models. Clearly, we are unable to estimate a quick “rule of thumb” measure of value using citations data, despite the initially promising nature of the data. At least for now, firms will still have to engage in expensive patent valuation by “experts”.

VII. References

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Tables

Table 1: Variables Description

Variable	Description
Relative Value	Surplus/Deficit of 5 year average return compared to industry (in %)
Absolute Value	5 year average return (in %)
Absolute Scope	Sum of Scope of Patents (Sum of number of claims)
Average Scope	Average Scope of Patents (Absolute Scope / Number of Patents)
Citations Made	Sum of Nb of citations made by individual patents
Citations Received	Sum of Nb of citations received by individual patents

Table 2: Summary Statistics

Variable	Observations	Mean	St. Deviation	Min	Max
Relative Value	216	-2.93	10.85	-30.6	52
Absolute Value	216	1.13	12.03	-40.2	42..6
Absolute Scope	216	1352.25	2937.78	4	19971
Average Scope	216	17.36	6.69	2	41.44
Citations Made	216	1021.89	2179.89	1	19771
Citations Received	216	31649.05	20242.37	175	61821

TABLES 3-4: Model results by Absolute and Relative Value

Table 3

Dependent variable is Absolute Firm Value	Coefficient	Standard Error	t-statistic
Independent Variables			
Relative Scope	0.002281	0.1238	0.02
Citations Made	-0.0004112	0.0003798	-1.08
Citations Received	-0.000016	0.000041	-0.39
Constant	2.013426	2.641803	0.76
Nb of Observations: 216			
R-squared:0.0063			

Table 4

Dependent variable is Relative Firm Value	Coefficient	Standard Error	t-statistic
Independent Variables			
Relative Scope	0.105555	0.110726	0.95
Citations Made	-0.000175	0.003397	-0.52
Citations Received	-0.000053	0.000036	-1.45
Constant	-2.913004	2.362997	-1.23
Nb of Observations: 216			
R-squared: 0. 0151			

Table 5-6: Elasticities of Variables

Table 5: Absolute Firm Value - Elasticities

Scope	0.035213526
Citations Made	-0.373665515
Citations Received	-0.004072194

Table 6: Relative Firm Value - Elasticities

Scope	-0.625890985
Citations Made	0.061080645
Citations Received	0.005181077

Table 7-8: Patent Citations Received as predictor for Firm Value

Table 7:

Dependent variable is Absolute Firm Value	Coefficient	Standard Error	t-statistic
Independent Variables			
Citations Received	-0.000016	0.0000406	-0.39
Constant	1.631275	1.524366	1.07
Nb of Observations: 216			
R-squared: 0. 0007			

Table 8:

Dependent variable is Relative Firm Value	Coefficient	Standard Error	t-statistic
Independent Variables			
Citations Received	-0.000509	0.0000363	-1.40
Constant	-1.317497	1.363772	-0.97
Nb of Observations: 216			
R-squared: 0.0091			

Table 9: Patent Citations, disaggregated by Technological Area, as predictor for Absolute Firm Value

Dependent variable is Absolute Firm Value			
Independent Variables	Coefficient	Standard Error	T-statistic
Cite 1 (Chemicals)	-0.0030621	0.0098251	-0.31
Cite 2 (Computers and Communication)	0.0039779	0.0029331	1.36
Cite 3	0.0163906	0.0154451	1.06
Cite 4	-0.0080557	0.0061264	-1.31
Cite 5	-0.025072	0.0105383	-2.43
Cite 6	0.0426014	0.277385	1.54
Constant	1.25911	0.983491	1.28
Nb of Observations		216	
Adjusted R-square		0.0563	

Table 10: Patent Citations, disaggregated by Technological Area, as predictor for Relative Firm

Value:

Dependent variable is Relative Firm Value			
Independent Variables	Coefficient	Standard Error	T-statistic
Cite 1 (Chemicals)	0.006572	0.0090003	0.73
Cite 2 (Computers and Communication)	-0.0001807	0.0026869	-0.07
Cite 3 (Drugs and Medical)	-0.0175911	0.0141485	-1.24
Cite 4 (Electric and Electronics)	-0.0033903	0.0056121	-0.60
Cite 5 (Mechanical)	-0.0132182	0.0096536	-1.37
Cite 6 (Others)	0.0234428	0.0254098	0.92
Constant	-2.804353	0.9009276	-3.11***
Nb of Observations		216	
Adjusted R-square		0.0093	

*** Significant at 1% confidence level

Figures

Figure 1: Investment Costs and Returns over time

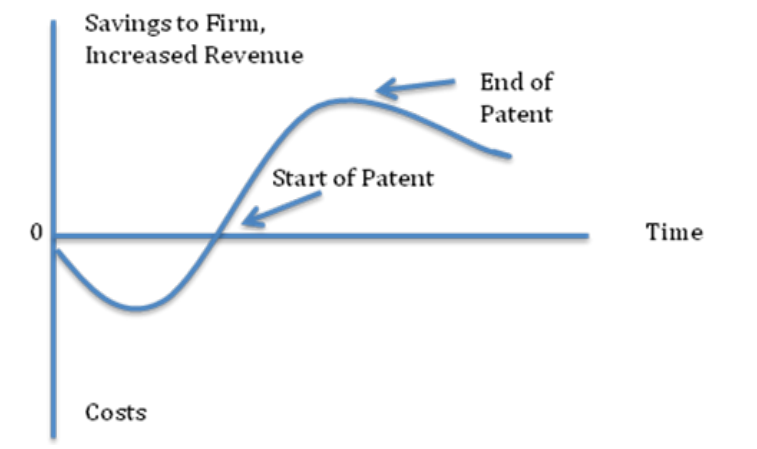


Figure 2: Profit Maximizing under a Monopoly

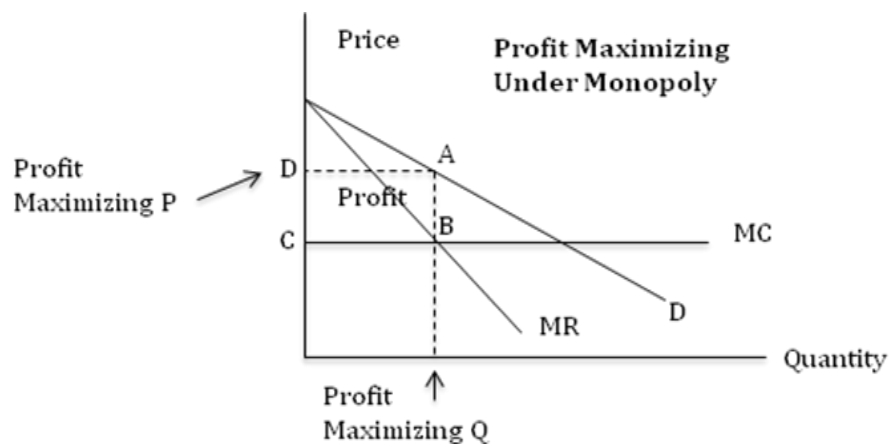


Figure 3: Predicted vs Actual Value (Absolute Firm Value)

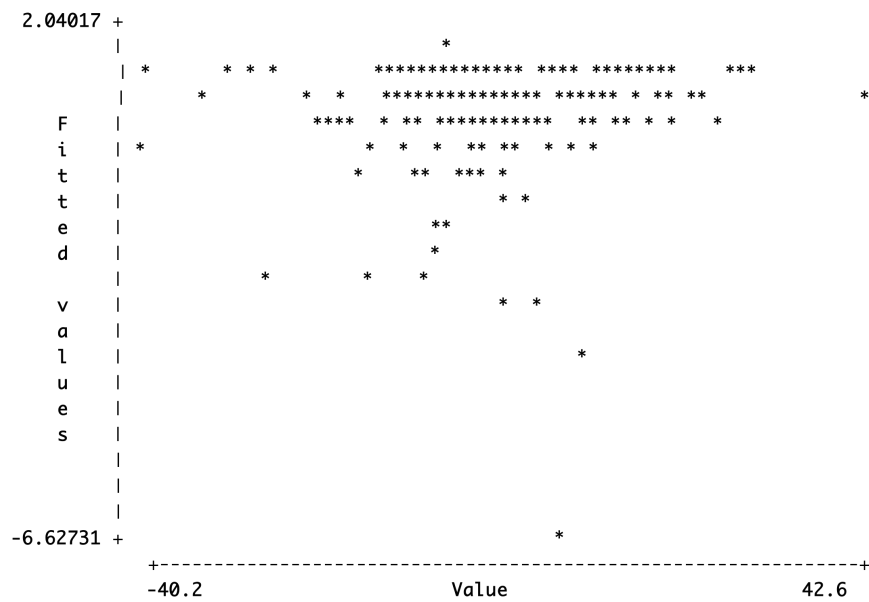


Figure 4: Predicted vs Actual Value (Relative Firm Value)

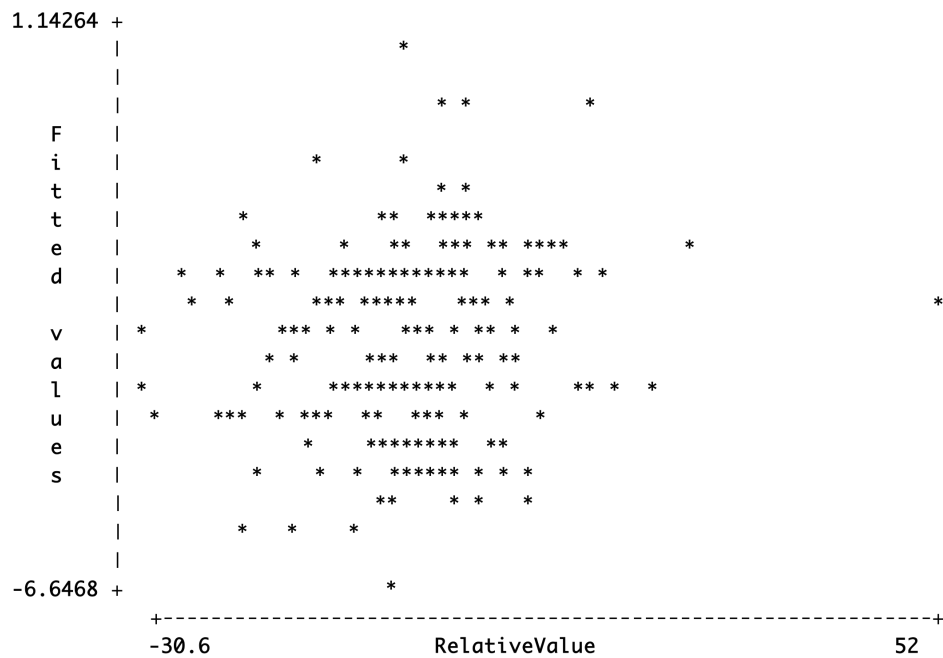


Figure 5: Residual vs Scope (Absolute Firm Value)

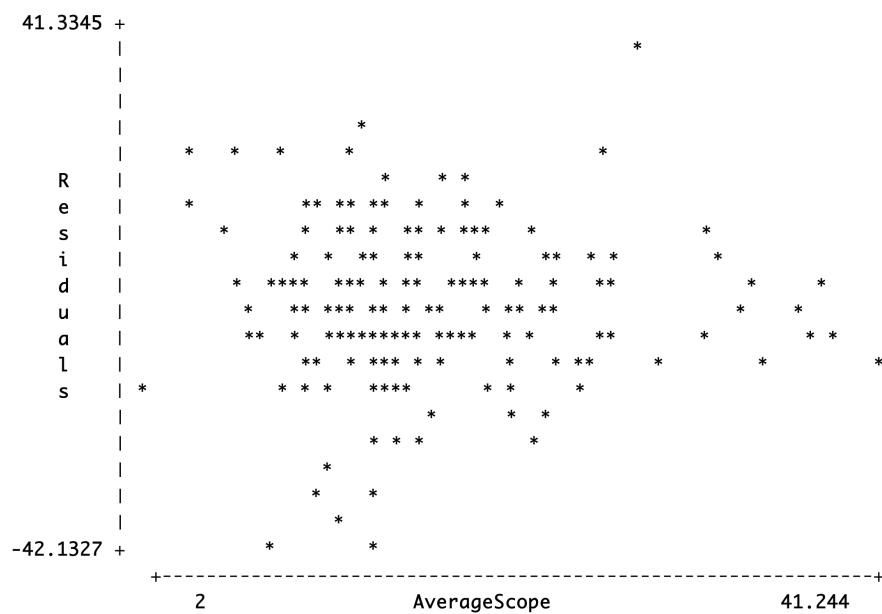


Figure 6: Residual vs Scope (Relative Firm Value)

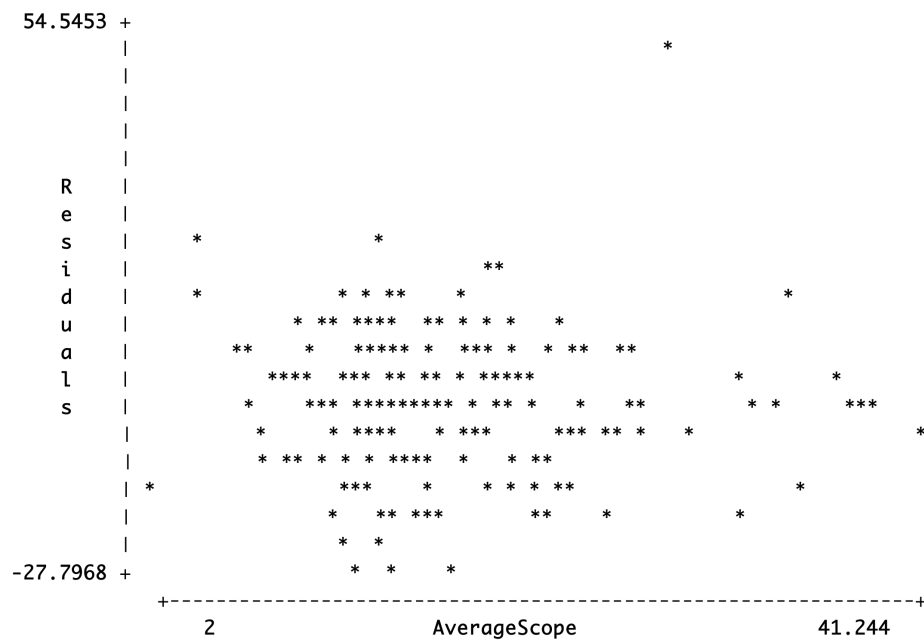


Figure 7: Number of Citations by Technological Category as predictor of Absolute Firm Value, Fitted Values vs Actual Values Plot

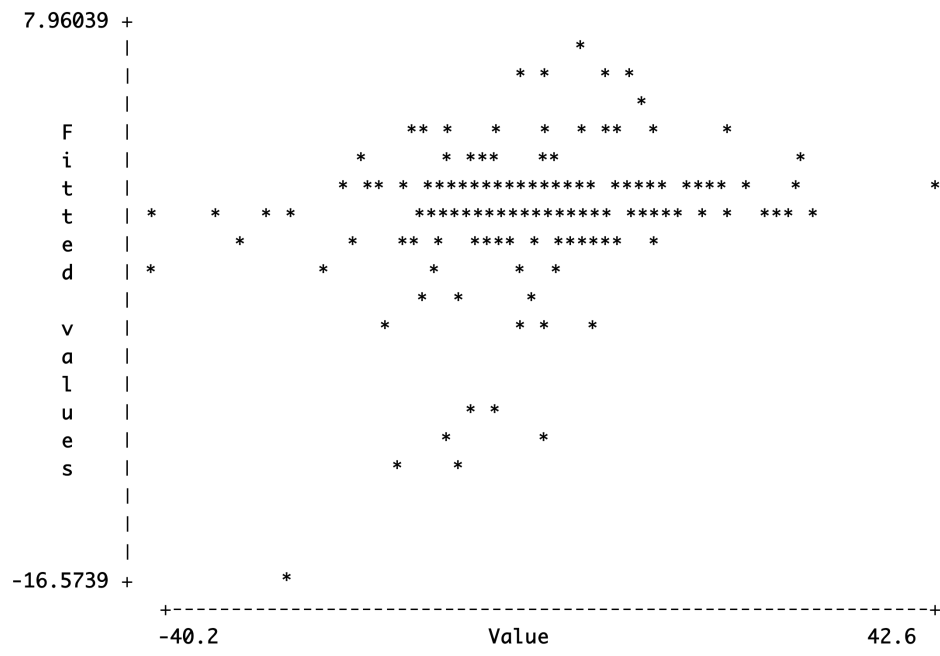


Figure 8: Number of Citations by Technological Category as predictor of Relative Firm Value, Fitted Values vs Actual Values Plot

