New Industry Creation and Originality:
Insight From The Funding Sources of University Patents

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University Knowledge, Originality of Patents and the Creation of New Industries

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Abstract

Scientific breakthroughs emanating from universities can be a trigger for the emergence of new industries such as in the paradigmatic case of biotechnology. Obviously, not all research conducted in the universities leads to radical departure from the existing technological trajectories. When a patent protection is granted to a discovery, it is possible to construct a proxy for the originality of the discovery based on patent citations. Patent originality has been long recognized in fostering the emergence of new technologies and industries. However, while a large body of literature exists measuring the impact of patent originality on a broad range of measures of firm performance, this paper aims at investigating the conditions driving patent originality. In particular, in providing the first empirical examination of the determinants of patent originality, this paper finds that the research context, as reflected by the funding source for the scientist, influences the extent to which intellectual property protected by a patent is original. Eventually, we propose that university scientists funded by their university, which has a more fundamental mission, have a higher propensity to generate patents that are more original. By contrast, university scientists funded either by industry or other non-university organizations have a lower propensity to generate more original patents.

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1. Introduction

The emergence of biotechnology in the 1970s provides a prototype for emergent industries. The commercialization of new knowledge played a key role. In the case of biotechnology, the underlying knowledge was developed in the university context by Herbert Boyer of the University of California at San Francisco and Stanley Cohen at Stanford University. Their laboratory experiments provided a compelling demonstration of the vast potential for DNA recombinant engineering to revolutionize not just agricultural products but also medicinal and pharmaceutical products as well.

It took more than the scientific breakthroughs emanating from universities to launch biotechnology. Rather, patent protection of key intellectual property provided a key platform for commercialization of the underlying science and its transformation into the new biotechnology products. The originality of the patents reflects the extent to which the underlying intellectual property developed by Boyer and Cohen was a radical departure from the extant technological trajectories.

Jaffe, A., Henderson, R. and M. Trajtenberg (1998) and Jaffe, Trajtenberg and Romer (2005) introduced and refined an important methodology for measuring the originality of a patent. Patent originality has been used in a number of studies to identify a broad range of measures reflecting firm performance, such as growth and survival (Cohen, Nelson and Walsh, 2002; and Jaffe, Trajtenberg and Romer, 2005). However, while patent originality has been extensively used to explain firm performance, there are virtually no studies explicitly identifying those factors conducive to patent originality.

The purpose of this paper is to explicitly analyze why some patents exhibit more originality than do others. In the following section, we draw on the literature initiated by Nelson and Winter (1982) and Dosi (1982) concerning the roles of technology trajectories and emergent technologies to develop a series of hypotheses linking patent originality to the research context in which the intellectual property was created. In particular, we propose that university scientists funded by their university, which has a more fundamental mission, have a higher propensity to generate patents that are more original. By contrast, university scientists funded either by industry or other non-university organizations have a lower propensity to generate more original patents. In the third and fourth sections of this paper, we subject these hypotheses to empirical scrutiny using a database linking patents by university scientists to their particular funding sources. In the last section of the paper, a summary and conclusions are presented. In particular, in providing the first empirical examination of the determinants of patent originality, this paper finds that the research context, as reflected by the funding source for the scientist, influences the extent to which intellectual property protected by a patent is original.

2. Originality and Emerging Technologies

The importance of innovation in stimulating productivity and economic growth has long been recognized in economic thought. For instance, according to Adam Smith, the division of labor allowed workers to do their jobs better and generate new methods of production, thereby driving economic growth. Later, Schumpeter introduced the concept of creative destruction as the constant introduction of innovations, rendering older things obsolete and fueling qualitative economic advancement (Schumpeter, 1942). From a different perspective, Solow used empirical evidence to reach the conclusion that the variation of output over time cannot be explained by variations of inputs only but rather, and to a larger extent, by qualitative technical change (Solow, 1967). Finally, since Arrow's seminal work (1962) growth theories and new growth theories developed various models to explain growth and variation in growth rates, highlighting the importance of labor productivity.

As important question in studying change in economic systems concerns the determinants of the innovation process, such as drivers of its rate and direction. Dosi (1982) and Nelson and Winter (1982) provided a compelling theoretical framework considering technology as knowledge, which includes not only knowledge codified in blueprints, manuals, publications, and patents but also know-how and organizational capabilities, which exhibit a tacit nature. Tacit knowledge (e.g. related to technical know-how or non-standard production) is costly to transfer, and transferability is limited by its embeddedness in individuals, teams and organizations. Moreover, if technology is perceived as knowledge embedded in individuals and organizations, its rate and direction are also driven by individual cognitive processes. In this view, Dosi (1982) introduced the concept of technological paradigm and trajectory. Technological paradigm defines the set of common heuristic, institutionalized ideas in a specific technological field and shared views about the future development of an artifact; technological trajectories include the selective, and cumulative nature of technological progress within a paradigm (Dosi, 1988). This approach to economics of innovationsuggests that the search process in discovery does not freely explore all the space of technological opportunities but is focused on a specific path which builds up on past knowledge and which is difficult to change.

The path-dependency of the technological progress is not *per se* a problem for a techno-economic system. For instance, many benefits can be derived from the continuous progress along a technological trajectory such as a higher level of predictability of research output, faster learning economies due to simplification and routinization of the process, scale economies, and easier production of complementary assets and components' interfaces. Over time, standardized knowledge on a technological trajectory allows an efficient routinization of the innovation processes by creating order and consequently reducing uncertainty. However, over time, path-dependency can end up in a cost of missed opportunities. New possibilities can arise along a different trajectory, or in times of revolutionary science, as part of a new scientific or technological paradigm. In these cases, cognitive and economic barriers due to path-dependency can hinder the shift of the system towards the new path. Even more, they can distort researcher assessment and introduce myopic behavior and status quo bias in the exploitation of the technological opportunities (David 1985). In this situation, an economic system can benefit from the production of original knowledge.Following Hall et al. (2001), originality refers to the characteristic of knowledge which does not cumulatively rely on knowledge from a specific trajectory and thus, which is able to escape the path-dependency trap. Original knowledge is a potential source of new ideas which can open new sectors and industries relying upon knowledge outside the existent technological path. Under the assumption of technological progress, which works in the way described by Dosi (1982, 1988), a system needs the ability to generate a certain degree of original knowledge to avoid severe technological lock-ins.

However, research oriented towards originality is rarely pursued by firms. As noted by Nelson (1959) and Arrow (1962), basic knowledge cannot always be used directly by the firm introducing it. Moreover, in this view, technology is simple information with the nature of a quasi-public good, reproducible at zero marginal cost, non-rival, and non-excludable (at least without the intervention of some institutions). Agarwal, Henderson and Bohner(2002) posit that such systematic underfunding of basic inventions results from a strong association of applied inventions with commercial success and inappropriability of results from basic inventions. The returns of investment in basic research are thus not fully appropriable by the innovator, and in equilibrium, this could lead to underinvestment with respect to a social optimum. Firms also have little incentive to invest in original knowledge because of the uncertainty linked with it. In an attempt to integrate theory on investment behavior and theory on searching capabilities, Henderson (1993) focused on sources of resistance to change. Martin and Scott (2000) discuss the lack of incentives for firms to invest in original and general knowledge. Their taxonomy includes factors ranging from limited appropriability, uncertainty, to lack of competencies.

The lack of incentives for firms to invest in original and general research has been the rationale since the World War II for public funding of university research. Combined with the traditional role of universities in reproducing existing knowledge(Martin 2003), policymakers financed universities to pursue research for its own sake (Geuna 2001). Research taking place in universities has been shown to play a key role in technological and other advancements. University research activities have been linked to product and process innovations (11% and 9% respectively; see Mansfield 1991) and productivity growth in private industry (Adams 1990). Some industries have seen important improvements related to university research, such as drug (Toole 2007) and pharmaceutical industry innovation contributing to lower hospital cost and increased life expectancy (Lichtenberg 2001, 2003). Other industries, such as biotechnology in the US, have been shaped in large part by university research (see Czarnitzki et al. 2011; Zucker and Darby 1997 and. 1999).

However, since the early 1980s, a shift in the rationale and nature of research funding has occurred in universities in both in the US and in Europe. As Geuna (1998) pointed out, this was partly due to greater student enrolment in universities and the rise in expectations for social returns from the society. These two events introduced irreconcilable dichotomy between the traditional task of curiosity driven research and research driven by societal need (Geuna 2001). This friction led to the institutionalization of new academic functions, such as "pursuing knowledge and its application for the creation of wealth" and "to serve the specific training and more general research supports needs of the knowledge-based economy at local, regional, and national levels" (Geuna 2001, p.617).

These changes in the rationale for the existence and nature of knowledge creation within the university occurred with a radical transformation of funding sources of university research. The extent to which institutional setting creates incentives for the university to generate wealth and cooperate with firms is driven by many factors and depends on national legislation. Some of these are (1) the introduction of the privilege for publicly funded institution to retain intellectual property of an innovation and (2) competitive mechanisms for resource allocation.

The Bayh-Dole Act of 1980 is a classic example of the first type of institutional change and paved the way for US universities to maintain ownership and patent intellectual property resulting from federally funded research, with provisions to share license revenues with the scientist/inventor (see Thursby et al., 2009). Professor privilege (professor retaining ownership of inventions) has been a key difference between the US and Europe, with faculty in Europe often providing patent rights to their research sponsors (see Geuna and Nesta, 2006; Crespi et al., 2006; Thursby et al., 2009). Changes in some European countries to institute similar legislation have been occurring, such as the removal of professor's privilege in Germany in 2002 (refer to Czarnitzki, 2001; Kilger and Bartenbach, 2002; Guena and Nesta, 2006). The Bayh-Dole Act remains the policy example of standard, and its impact on university patents in the United States has been analyzed extensively across several years (see Mowery et al., 2000; Mowery and Rosenberg, 1998; Sampat et al., 2003; Mowery and Zeidonis, 2002). While the Bayh-Dole Act supported university ownership of innovations, several studies (Thursby and Thursby, 2005; Audretsch et al., 2006; Markman et al., 2006) find evidence of patent assignments outside universities. Thursby and Thursby (2005) find that 29% of patents in a sample across universities were assigned to firms; Audretsch et al (2006) report 30% assignment of at least one patent to firms among scientists funded by the National Cancer Institute; in a study of more than 50 universities, Markman et al. (2008) report a similar trend of 33% of patents assigned externally. Noting that some empirical studies assume patents assigned outside universities result from circumventing university technology transfer offices (Audretsch et al., 2006; Markman et al., 2008), Thursby et al. (2009) ask whether patents assigned outside universities are in fact legitimately assigned. They consider that patents can be assigned in four types: university assignment, firm assignment where the inventor is a principal, firm assignment where the inventor is not a principal, and unassignment (ownership by the inventor). They find that firm-assigned patents are more incremental than university-assigned patents, and that firm assignment of patents results largely from consulting and not university-conducted research. Additionally, Thursby et al. (2009) find that a higher inventor share increases the chances of university assignment of a patent versus firm assignment in which the inventor is a principal, but has no effect on other types of patent assignment.

The second type of institutional change is discussed by Gulbrandsena and Smebyb (2005), who find evidence that professors involved in research with the private sector perceive themselves as more applied than others. Reduced public funding availability in Europe (Guena and Nesta, 2006) and competitiveness among universities for public funds has created incentives for private and nonprofit funding partnerships. Czarnitski et al. (2007) find differences in scientific performance based on funding source among German professors: Patents in partnership with nonprofits enhance performance whereas corporate patents negatively affect scientific performance. Geuna and Nesta (2006) show there is an effect impact of a growing number of patents after the shift of university funding, but this effect is heterogeneous among sectors.

Most studies have examined the overall number of university patents resulting from funding changes or policy changes. Yet counting total patents does not provide the full story (see Marco, 2006), and the technological importance of an invention (Hagedorn and Cloot, 2003; Trajtenberg, 1990; Henderson et al., 1995) is the basis for a subgroup of studies on the quality of patents. Understanding the determinants of patent quality can yield important implications for ongoing policy design, particularly as more countries around the world are adopting Bayh-Dole types of legislation. However, evidence on the quality of patents is not conclusive, and typically when data are available, they are difficult to disaggregate by funding source. For instance, Henderson et al. (1998) show a decrease in the quality of university patents between 1965 and 1988 at the aggregate level. Instead of looking at originality, they used a measure of quality as the dependent variable, which is a non normalized measure of total citations. Their key finding is that the relative importance and generality of university patents declined despite an overall increase in university patents, and this is attributed mainly to a higher number of low-quality patents. Mowery et. al (2001) find weak evidence of a decrease in the quality of university patents, which disappears if the analysis take into account the experience of the expert. Mowery and Zeidonis (2002) measure patent importance as citations during 6 years after issue and study patent trends in three US universities (University of California, Stanford University and Columbia University) before and after the passing of Bayh-Dole. They find no decline in importance or generality of patents issued after 1980 at University of California and Stanford University; they find overall that the effects of Bayh-Dole may be “as important as any effects of the act on the internal research culture” of US universities (Mowery and Zeidonis,2002,pg.399). Aldridge and Audretsch (2011) find that over twenty-five percent of scientists who have at least one patent start a firm.

In this paper, we surmise that both types of research activities still coexist within the university: Publicly-funded research and privately co-funded applied research. Thus, we investigate whether this change in the social mission of the university and the related change in funding sources negatively affected the originality of university patents.

This broad hypothesis is rooted in the trade-off between curiosity-driven research and research driven by societal need. In order to answer this question, we test for the impact of financing sources of projects which led to patent production. We identify university research which is financed directly by the university and federal projects issued through tender or funded by the private sector, thereby creating as a sample allowing us to observe whether the primary source of investment is federal, industry, university or nonprofit funding. Along the line of reasoning discussed above, we expect that publicly funded research should be more original than privately funded research.

2.1. Hypotheses

In the theoretical framework, we suggest that university research is a key instrument for keeping a reasonable allocation of resources employed towards the exploration of new areas in technological space; mitigating the risk of lock-in of the cumulative and selective nature of the discovery process is a related concern with important implications, inside and outside universities. Recent changes in the funding rationale of academic research might have modified incentives schemes (for more see Guena and Nesta, 2006; Czarnitzki, 2001) and thus, challenge the task of university research behavior.

Past research showed that originality, a measured based on patents citation counts, may be mildly decreasing over time. However, this is not always supported (Mowery and Zeidonis, 2002) or not conclusive and becomes not significant when other controls are added (see Mowery et al., 2001 and Aldridge and Audretsch, 2011).

We argue that whether a patent is assigned to a university or not is not the correct explanatory variable to grasp the effect of the changed incentives schemes upon the originality of the research (see Marco, 2006, for a discussion of patent counts). What really matters is the trade-off between curiosity-driven research and research driven by societal need. In order to disentangle these effects, we conclude that for each patent, it is worth examining the funding source of its specific project. This information may help explain the variation in originality across patents. Indeed, within the universities various types of funding schemes can coexist, such as public, private, profit or non-profit.

First, along the lines discussed above, we expect that a patent funded by the university to be on average more original than other. This effect might bring more empirical evidence to the ongoing discussion about the quality of the university patents. The big picture by Henderson et al. (1998) that academic research has declined in quality over time has already been mitigated by other studies looking at more disaggregate levels. Moreover, academic patent quality depends on factors including sector, university, technology transfer office (Mowery, 2001; Mowery and Zeidonis, 2002). This paper could add further ease Henderson et al. (1998).

Hypothesis 1: university funded projects lead to patents of higher originality

Secondly, we can argue the opposite for privately funded research: if firms have few incentives to perform basic and original research because of lack of appropriability and inherent uncertainty, we can expect that they also fund less original research

Hypothesis 2: privately funded projects lead to patents of lower originality

Third, university funded research is not the only mechanismthatgovernment can finance research activities. Indeed, we should distinguish among two different kinds of public funding: university-based and direct government funding based on calls for application. This distinction is crucial because government projects are not usually oriented toward existing societal needs (Geuna 2001) and thus, can probably reinforce path-dependence of mainstream science and technology, not necessarily pushing for original research.

Hypothesis 3: government funded projects lead to patents of lower originality

Fourth, the legal and economic status of the source of the funding should also be taken into account; therefore, we look at profit versus non-profit status of the funding organization. The direction of this effect is not clear a priori. To our knowledge, there are no empirical studies examining this question and existing theory does not yield a clear hypothesis. Hull and Lio (2006) develop a model to assess the innovation propensity of non-profit organizations and discuss the complex interactions among three elements which differ between profit and non-profits: strategic vision, financial constraints and strategic constraints. Their model is a useful way to categorize the discussion but does not provide any direct hypotheses. Furthermore, we investigate whether the non-profit nature of the source of funding has any effects. We do not formulate an explicit research hypothesis here.

3. Material and Methods

3.1 Data

We use two data sources. The first is the NBER U.S. Patent Citations Data File, which contains for each patent granted by the USPTO between 1975-2006 citation data and technological class of belonging of a patent. Secondly, we use information on scientists who have been awarded a Nationcal Cancer Institute (NCI) grant in the years 1998-2004. Patent records have been match with the NCI recipient scientists, using Structured Query Language (SQL) coded to extract and manipulate data. As taken from Audretsch et al 2006, a match between the patentee and NCI awardee databases was considered to be positive if all four of the following necessary conditions were met:

(1) A positive match was made with the first, middle, and last name. If, for example, the scientist did not have a middle name listed on either the NCI award database or the patent database, but did have a positive first and last name, this first condition was considered to be fulfilled.

(2) The second criterion involved matching the relevant time periods between the two databases. Observations from both databases were matched over the time period 1998-2004, which corresponds to the initial year in which observations were available from the NCI database (1998-2002) and the final year in which patents were recorded in the patent database (1975-2004). Because applications of patents may take anywhere from three months to two years to be issued, the 2003 and 2004 USPTO patent records were included in our query. Issued patents from 1998 to 2004 by NCI scientists fulfilled the second criterion.

(3) The third criterion was based on location. If the patentee resided within an approximate radius of 60 miles from the geographic location of the university, the third condition was fulfilled.

(4) The fourth criterion was based on USPTO patent classification. Using the USPTO patent classification code, all patents were separated into respective coding groups. Patents which did not fall under the traditional categories of biotechnology were identified. All non-biotech patents were evaluated, and patents such as "Bread Alfalfa Enhancer" were rejected as an NCI scientist patent (see Appendix A for a distribution of patent categories).Based on these four matched criteria, a subset of 65 distinctly issued patentees were identified between 1998 and 2004 with a total of 167 patents who responded to a set of questions including:

Did you have any other major sources of funding (totaling over $750 thousand) (yes/no):

If yes, please choose the source(s) of funding that apply:

A) Nonprofit B) Governmental C) Your University/Institution D) Industry E) Other

[5]3.2 Variables

, The dependent variable of the model is patent originality. Following Tratjenberg et. al (1996), we estimate the originality of each patent in the dataset. This is calculated as an index score measuring each patent's prior patent citations. Funding source is operationalized as coming from university, nonprofit, industry or government. In addition, total NCI grant funding, a primary source of government funding for the period 2000-2004, is measured for each scientist. Following Aldridge and Audretsch (2011), we include variables for both human capital and industry linkage. Human capital is operationalized by measuring average citations per publication in ISI, reported for each scientist from 2000 to 2004. Scientist-industry linkages are operationalized by two variables selected to reflect scientist connections to private industry. The first measure of social capital is board membership, a binary variable reflecting scientist participation on a board of directors or scientific advisory board. The second measure of social capital is industry co-publications, counted as the number of ISI publications an NCI scientist shared with a private industry employee who had an address field of co, corp, inc, ltd, llc and/or coltd. The third measure of social capital is industry-research lab co-publications, counted as the number of ISI publications an NCI scientist shared with a private industry employee who had an address field of reslab.

Based on Levin and Stephan (1991) and Stephan and Levin (1992), and following Aldridge and Audretsch (2011), we include controls for scientist age and gender. Scientist age is calculated from the year the scientist was born; gender is reported as a dummy variable, where a male scientist is assigned a value of one and a female is assigned a value of zero. The effects of a scientist's institution context are controlled for in two variables. The first variable of Public Institution is included due to the differing nature of private and public intellectual property

[5] The 65 patenting scientists were "Googled" to obtain their e-mail and telephone information. The records could generally be found by typing their full name, university and the word "oncology". The ensuing patentee e-mail accounts and telephone numbers were then collected and registered in the scientist database.

ownership. The second variable identifies if the scientist's university was a recognized NCI Comprehensive Center. This variable controls for any potential agglomerating effects of knowledge specialization at the scientist university.

The next section controls for the quality of patent. The universities TTO age is controlled for due to the potential quality of TTO office. For example, an older TTO may have more experience and knowledge in a patent application and therefore identify less backward patent citations in its application. The second variable is number of prior patents. Using Stuart (xx) we control for the number of patents issued to the scientist prior to 2000. We also control for the type of patent which was issued using the NBER two digit patent classification code. This control, for example, allows us to control if the scientist was issued a patent in the subfield of drugs or medical instruments.

[Table 1. Dependent Variable]

[Table 2.Description of Independent Variables.]

[Table 3. Means and Standard Deviations.]

3.3 The model

We use this data we aim at testing a series of hypotheses concerning the source of funding as determinant of a patent's originality (O). Thus, we suggest a model where the variation in the originality of a patent is explained by its source of funding (S) and by other covariates which might affect the variance of the dependent variable as well. Specifically, we consider three groups of controls. The first one consists of demographic characteristics (D) of the inventor such as gender or age and they proxy the different attitude towards research in the life cycle of an individual. Others variables try to capture some unobservable quality of the scientist linked with her human capital, her linkage with the industry, the quality of the institution she is coming from (T). The third group of controls consists of industry dummies and takes into account the different research patterns across industries (I). We thus, estimate the following model:

$$O = S\boldsymbol{\beta} + \boldsymbol{D\gamma} + \boldsymbol{T\delta} + \boldsymbol{I\theta} + \boldsymbol{\varepsilon} \qquad \textbf{(1)}$$

where O is the vector of n observations of patent originality, S is a $n \times p\text{-}1$ matrix, where p is the number of dummies variables indicating the sources of funding, and D, T, and I are the matrix of observations for each control group. $\boldsymbol{\varepsilon}$ is the vector of error terms. Although we control for various factors, which capture various source of heterogeneity of the sample, heteroskedasticty cannot be excluded This issue is solved by using a robust estimation of the variance matrix. Concerning the issue of endogeneity, it should be noticed that we derive originality from a dataset of patents; patents are an output of the discovery process. . Second, we explain originality with inputs of the discovery process – i.e, funding sources. Thus, reverse causality should not be a concern. Morevoer, assuming a more complex process of innovation,, a correlation between covariates and the error terms, if any, would increase the standard deviation and reduce accuracy of our estimator. However, the sign of the coefficients would remain unchanged. For this reason, in the worst case scenario, the estimator would be almost consistent and, thus, not excessively affect the interpretation of the results. In the following sections, we describe the data the variables, and present the results of regression

3.4 Results and discussion

Table 4 depicts six models which differ in the number of controls used. Results hold across models and explain 30% of the variance of originality. Given the complexity of the research process, the use of patents as a problematic proxy for inventive activity, and the size of the sample, we consider a fitness of 30% as satisfying. The strongest result is that the university funding has a positive impact on the originality of a patent. This result is in line with the expectation aor the first hypothesis and challenges the common view that university patents have a lower quality on average. The focal point is not whether a patent is assigned to a university or not but its source of funding. Only in cases where university is the source of funding does university research maintain its traditional role of pursuing original research.

In addition, the other sources of funding do not have a significant impact on the originality of a patent. In other words, while a negative or non-existing effect of private funding is the expected result of hypothesis 2, the non–significance of governmental funding is a robust one which challenges the common view of the policy makers. As previously discussed, few scholars in the economics of science highlighted that the new rationale in governmental funding allocation based on competitive call for application might distort a researcher's incentives to explore original paths (Geuna, 2001). However, this is the first empirical observation of this effect. Both the previous theories on the issue and this piece of evidence suggest hat if the aim is to allocate resources to a pure curiosity driven research, which mitigate the path-dependency of a system, a government should leave freedom to universities. The null or non-significant coefficient of NCI grant further strengthens this implication: funding made available for cancer research are not supposed to run the risk of being employed in dead-end projects. Also the profit vs. non-profit nature is not significant. Non-profit organizations have a very complex difference and difference strategic and financial constraints from private one. According to this research, the net effect does not point toward the creation of original knowledge.

We then have a set of variables which control for the talent and the linkages of an author with the institutional setting. The negative and significant impact of average ISI citation number per publication of an author suggests that originality is not necessarily always a breakthrough in the scientific paradigm. On the contrary, if path dependency is not a problem *per se*, original projects turn very frequent to be unsuccessful or to reach a dead-end.

The variables controlling for the linkages of a scientist with the institutional setting corroborate the idea that originality is stronger for those authors focused on their university work only. If an author sits in a board of directors or in an advisory board, she will produce less original patents. On the contrary, co-publishing with a private company or with a research lab and having a direct affiliation to a university or a NCI center does not have a significant effect.

[Table 4. Regressions]

Models 3-5 include dummies for the main technological class of the patent. They do not report a significant coefficient with the exception of the dummies for "drugand medical" which has a negative impact on originality. Once again, a very applied field with routinized innovation such pharmaceuticals (Nightingale, 2000) shows little originality. Finally, variables such as age and gender do not have any effect. Indeed, there is no reason to assume a variance of the propensity to be original clustered around these demographic variables.

All in all, we can conclude that when the source of funding is not the university, incentives to explore the scientific and technological space outside the existing technological trajectories tend to vanish independently by the characteristics of the scientist. On the one hand, this evidence is good news and rejects the hypothesis that over time the quality of research done in the university has been declining. On the other hand, we should warn policy makers that the changed rationale for funding allocation in western countries is distorting the incentive schemes in a unintended way. The new task assigned to the university to generate more knowledge, which can be directly applied by the private sectors, seems to be fulfilled. However, the traditional role of the university of providing basic and original research is shrinking. Partly, this is the intended consequence of the creation of more linkage with industry. We also question whether governmental funding is intended to reduce originality and favor path-dependency or if this is an unintended consequence of the competitive funding allocation scheme of the governmental research call.

It has to be stressed again that path-dependency is not harmful, but on the contrary, it is an efficient way to organize the process of discovery. Thus, the system is facing a trade-off between an efficient process of discovery which might lead to lock-in situations and a costly process of trial and error in original research which might lead to the emergence of new technology and industries. The balance is a policy question, but the tools to be used should be carefully analysed and evaluated to avoid unintended consequences.

As a caveat, we should admit that the incentives scheme generated by the opportunities of funding has a much more complex nature than what this data can grasp; thus, the vast set of possible effects cannot be fully disentangled here. In any case, this results call for both more empirical research to make this result more robust and a stronger micro based theoretical framework which link a researcher's incentives and the source of funding.

4. Conclusion

In his *Journal of Economic Literature* article surveying the literature on the use of patents as a measure of innovative activity, Griliches (1990) points out that patents are not a homogeneous phenomenon but instead reflect inherent heterogeneity in the underlying value of the intellectual property they have been granted to protect. Griliches identifies the originality of patents as a key characteristic which exhibits considerable heterogeneity across intellectual property.

More recently, Jaffe, A., Henderson, R. and M. Trajtenberg (1998) and Jaffe, Trajtenberg and Romer (2005) have succeeded in addressing Griliches' (1990) concern about patent heterogeneity by developing methodologies for measuring the degree of originality associated with any given patent. In fact, a growing body of empirical work confirms Griliches' (1990) assertion about the inherent variability of patent originality.

Patent originality, which reflects a highly original value of the underling scientific research, has been long recognized (Nelson and Winter, 1982; Dosi, 1988) in fostering the emergence of new technologies and industries. However, while a large body of literature exists measuring the impact of patent originality on a broad range of measures of firm performance, this paper is the first study to actually ask why some patents are more original than others. The hypotheses and empirical results confirmed in this paper suggest that the answer has to do with the heterogeneous nature of the underlying research undertaken by the university scientist granted the patent. Research which is supported by the industry tends to generate patents which are less original in nature. By contrast, research supported by universities, which has less of an applied focus, tends to generate patents which have a greater degree of originality.

An important qualification of these findings is that they apply only to a limited area of science and technology. Future research needs to examine the determinants of patent originality for a broader scope of scientific and research contexts.

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[Table 1. Dependent Variable]

Dependent Variable	**Description**
Originality	An index score measuring how radical each patent was by measuring the patent's prior patent citations

[Table 2.Description of Independent Variables.]

Independent Variables	**Description**
University Funding	Binary variable, for scientists indicating that they received at least $750,000 of funding from a university source, University Funding=1
Nonprofit Funding	Binary variable, for scientists indicating that they received at least $750,000 of funding from a university source, Nonprofit Funding=1
Industry Funding	Binary variable, for scientists indicating that they received at least $750,000 of funding from a for-profit source, Private Funding=1
Government Funding	Binary variable, for scientists indicating that they received at least $750,000 of funding from a governmental source, Government Funding=1
NCI Grant	Total amount of NCI funding received by a scientist from 2000 to 2004
Avgcipub	The average citation per publication in ISI from 2000 to 2004

Industry Co-Pub	The number of ISI publications a NCI scientist shared with a private industry employee who had an address field of; co, corp, inc, ltd, llc, and or coltd
Industry ResLab Co-Pub	The number of ISI publications a NCI scientist shared with a private industry employee who had an address field of; reslab
OnBoardDirect	Binary variable, for scientists indicating that they sat on either a board of directors or science advisory board, Board=1
Scientist Age	The year the scientist was born
Male	Binary variable, where a male=1
TTOFoundYear	Year when the scientist's university TTO was founded
Public Institution	Binary variable, for a scientist who was affiliated to a public university, Public Institution=1
NciComcenter	Binary variable, for a scientist whose institution is recognized by NCI as a comprehensive center for cancer research, NCI Center=1
Prior Patents	Count, The number of issued patents a scientist had, 1975 – 1998
Two Digit NBER Patent Sub Category Code;	
PCResins	Two digit patent subcategory in the patent field of Chemicals
PCBio Tech	Two digit patent subcategory in the patent field of Drugs and Medical
PCMiscel. Chem	Two digit patent subcategory in the patent field of Chemical
PCComputer Hard/Software	Two digit patent subcategory in the patent field of Computers and Communications
PCSurgery and Med Inst	Two digit patent subcategory in the patent field of Drugs and Medical
PCOrganic Componds	Two digit patent subcategory in the patent field of Chemical
PCDrugs	Two digit patent subcategory in the patent field of Drugs and Medical

[Table 3. Means and Standard Deviations.]

Variable	Obs	Mean	Std. Dev.	Min	Max
Patent Originality	167	0.327	0.289	0	0.826
University Funding	167	0.156	0.364	0	1
Nonprofit Funding	167	0.168	0.375	0	1
Industry Funding	167	0.329	0.471	0	1
Government Funding	167	0.365	0.483	0	1
NCI Grant	167	$2,578,126	$1,612,474	$1,194,332	$9,009,597
Avgcipub	167	26.662	22.068	1.667	130.365
Industry Co-Pub	167	3.467	4.475	0	27
Industry ResLab Co-Pub	167	0.246	1.832	0	23
Onboarddirct	167	0.605	0.490	0	1
Scientist Age	167	57.078	7.376	41	73
Male	167	0.880	0.326	0	1
Ttofoundyear	167	1981.138	8.739	1940	1996
Public Institution	167	0.461	0.500	0	1
Nci Compcenter	167	0.515	0.501	0	1
Prior1998patents	167	6.257	6.697	0	27
PCResins	167	0.216	0.412	0	1
PCBio Tech	167	0.683	0.467	0	1
PCMiscel. Chem	167	0.066	0.249	0	1
PCComputer Hard/Software	167	0.060	0.238	0	1
PCSurgery and Med Inst	167	0.102	0.303	0	1
PCOrganic Componds	167	0.323	0.469	0	1
PCDrugs	167	0.377	0.486	0	1

[Table 4. Regressions]

	Model 1	Model 2	Model 3	Model 4	Model 5
Dependent Variable	originality	originality	originality	originality	originality
University Funding	0.243	0.327	0.34	0.266	0.25
	(2.60)*	(4.10)**	(3.31)**	(2.23)*	(2.23)*
Governmental Funding	-0.049	-0.051	-0.031	-0.027	
	-0.86	-0.96	-0.56	-0.46	
Industry Funding	-0.039	0.013	0.035	0.05	0.053
	-0.54	-0.19	-0.54	-0.72	-0.76
Nonprofit Funding	0.033	-0.043	-0.058	-0.08	-0.074
	-0.35	-0.45	-0.52	-0.72	-0.66
NCI Grant		0	0	0	0
		(1.80)+	-1.36	-0.95	-0.91
AvgCiPub		-0.004	-0.005	-0.006	-0.006
		(3.79)**	(3.94)**	(4.32)**	(4.32)**
Industry Co-Pub		0	0.001	0.003	0.002
		-0.03	-0.12	-0.39	-0.35
Industry Reslab Co-Pub		0.006	0.005	0.004	0.003
		-0.88	-0.72	-0.51	-0.39
OnBoardDirct		-0.126	-0.146	-0.121	-0.126
		(2.22)*	(2.29)*	(1.84)+	(1.88)+
Scientist Age			0.001	0.003	0.003
			-0.25	-0.92	-0.87
Male			0.058	0.075	0.081
			-0.64	-0.79	-0.84
TtoFoundYear			-0.003	-0.005	-0.005

			-0.86	-1.38	-1.5
Public Institution			-0.071	-0.088	-0.087
			-1.17	-1.37	-1.38
NciCompCenter			0.016	0.01	0.018
			-0.28	-0.17	-0.35
PCResins				-0.069	-0.059
				-0.47	-0.41
PCBio Tech				-0.166	-0.161
				-1.14	-1.13
PCMisc. Chem				-0.142	-0.136
				-1.01	-0.99
PCSurgery and Med Instrm.				-0.022	-0.021
				-0.29	-0.27
PCOrganic Compounds				-0.084	-0.079
				-1.21	-1.16
PCDrugs				-0.104	-0.104
				(1.83)+	(1.84)+
Constant	0.315	0.561	6.09	9.774	10.27
	(6.58)**	(8.26)**	-0.93	-1.45	-1.56
Observations	167	167	167	167	167
R-squared	0.1	0.23	0.25	0.3	0.3

Robust t statistics in parentheses

+ significant at 10%; * significant at 5%; ** significant at 1%