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The Links Between Hotspot Patents and Publicly Funded Scientific Research

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The links between hotspot patents and publicly funded scientific research

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Abstract

Previous studies have examined in detail the links between scientific research and technological development. This paper contributes to this body of research, while focusing the analysis on the contribution of publicly funded science to the development of important, high impact technologies. Our results indicate that patents that cite scientific papers funded by government agencies are more likely to become high impact, hotspot patents than patents that do not have such a citation link to publicly funded scientific research. The importance of this scientific foundation can be seen across a range of new technologies, including biotechnology, semiconductors, computer networking and telecommunications.

Keywords: patents; citations; scientific papers; public funding

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Introduction

The relationship between scientific research and technological development has been the subject of extensive research by science and technology analysts. In particular, the contribution of publicly funded science to the development of new technologies has been examined in detail, in order to gain insights into the role of public funding of scientific research. The purpose of this paper is to contribute to this debate by examining the extent to which public science forms the foundation for influential technological developments. In addition, the paper evaluates the relative contribution of scientific papers funded by different government agencies. It also examines whether scientific research funded by a combination of government agencies has a greater or lesser impact on important technological developments.

This paper has two main sections. In the first section, we introduce a new method for identifying technologies that have a particularly strong impact on the latest technological developments. This method is based on the analysis of citations from recently issued patents to earlier patents. In the second section of the paper, we examine the relationship between these high impact patents and publicly funded scientific research. Specifically, we examine the question of whether patents that reference scientific papers supported by government agencies are more or less likely to become high impact patents. If they are more likely to become high impact patents, this suggests that technologies that build on publicly funded science have a greater chance of influencing future technological developments.

Background

Numerous studies in recent years have examined the relationship between scientific research and technological development, and how the former provides an important foundation for the latter. Turney (1991) argued that basic scientific research lies at the core of advances in scientific understanding and technological innovation, although the

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relationship is often complex. Based on survey evidence, Mansfield (1991) estimated that 10% of industrial innovations would not have occurred as quickly (or at all in some cases) without the contribution of scientific discoveries reported in academic research.

Other researchers have also used empirical methods to examine the benefits of public investment in scientific research. For example, Griliches (1991) quantified the economic spillovers that occurred as a result of scientific research. Meanwhile, Narin et al (1997) demonstrated that public science forms an important foundation for industrial innovation. This study revealed that over 70% of scientific papers cited by U.S. industry patents are authored by public institutions, rather than by companies. This led the authors to conclude that public science plays an essential role in supporting U.S. industry. McMillan et al (2000) used a similar approach, but focused their analysis on a single industry. This study showed that, in biotechnology, public science forms an important foundation for the innovations associated with many companies.

Both the Narin study and the McMillan study referred to above use citation links between patents and scientific papers to examine the links between technological innovations and scientific research. This paper also uses a citation-based approach to examine these links between science and technology. However, this paper does not examine the impact of publicly funded science upon technological advances in general. Instead, our analysis focuses on the links between publicly funded science and high impact technologies that have a strong influence on recent technological developments.

In order to implement this analysis, it was first necessary to develop a method for identifying high impact technologies. We used patent citation analysis, which is based on the examination of citation links between different generations of patents. When a patent is applied for, its inventor must demonstrate that the invention is novel, useful, and non-obvious to someone with expertise in the same technology. To achieve this, the inventor cites to earlier patents and papers as prior art, and explains how the new patent improves on the earlier inventions. The patent examiner may also add citations to earlier patents that limit the scope of the new invention.

Patent citation analysis is based on the idea that patents cited by many later patents tend to contain important ideas upon which numerous later inventors have built. This does not mean that all important patents are highly cited, nor that every highly cited patent is important. However, numerous validation studies have revealed the existence of a strong positive relationship between citations and technological importance (see Breitzman and Mogee (2002) for a review of validation studies). For example, Carpenter et. al. (1981) found that patents related to IR 100 invention awards are cited twice as often as typical patents. Also, Albert et. al. (1991) demonstrated that patents identified by industry experts as important were cited frequently by later patents. Other studies have revealed a positive relationship between patent indicators and various financial indicators, including stock market valuations (Deng, Lev and Narin 1999), stock price movements (Thomas, 2001), and increased sales and profits (Narin, Noma and Perry, 1987).

Methodology

The methodology presented in this paper contains two elements. The first element involves developing a method for identifying technologies that have a strong impact on recent technological developments. The second element involves linking these high impact patents to research funded by public organizations.

Identifying High Impact Patents

As mentioned above, the technique we used to identify high impact technologies is patent citation analysis. The simplest way to approach patent citation analysis is to count the number of citations received by each patent in a particular study. Using this approach, the assumption would be that the patents cited most frequently are the most influential in the analysis. However, such an approach is problematic, particularly because older patents have had a longer period to accumulate citations. Also, patents may have been influential in a previous period, but their impact has faded over time. Simply counting citations may therefore bias the analysis towards older patents, some of which may have received most of their citations many years ago.

In this study, our purpose was to identify patents whose impact on recent technological developments is particularly strong[1]. As part of this process, we were particularly interested in patents that had been cited relatively infrequently in earlier periods, before receiving numerous citations in the most recent period. We define such patents as 'hotspot' patents. The pattern of citations to hotspot patents may show that inventors of the latest technologies have rediscovered an earlier technology. Alternatively, complementary technologies may have advanced sufficiently to make the earlier technology feasible, either in technological or financial terms. Such conditions may show the start of a new direction in the development of technology, with new patents building on these earlier hotspot patents.

Hotspot patents differ from patents that have been highly cited continuously over many years. We refer to the latter group of patents as 'citation classics'. Citation classics tend to represent groundbreaking older innovations that are still being refined through incremental developments. As such numerous patents cite them over many years. They continue to be highly cited, but many of the recent patents that cite them represent incremental advances on the earlier technology, rather than the rediscovery of a previously ignored or impractical technology. Examples of citation classics include the LCD panel, the Ethernet, the laser printer, the disposable ink-jet head, high absorbency disposable diapers, nicotine patches, and cardiovascular stents. Patents are still being filed in these technology areas, but they tend to offer incremental advances on well-established technologies.

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[1] One argument against the use of patent citation analysis is that patents do not reflect the latest technological developments. Since patents take an average two years to issue, it has been argued that they do not adequately capture fast moving technologies. However, this argument does not necessarily reflect the nature of invention and innovation. In particular, although patents take a long time to issue, products take far longer to hit the market.

A few examples highlight this process. The Segway personal transport was first shown to the press in 2002, and was first available to the public in January 2003. The patents for this revolutionary device were filed as early as January 1999, and the first issued in October 1999. Side impact airbags were first available in high-end BMW cars in 1996, but patents for such devices were issued in 1992 and earlier. Organic LEDs (OLEDs) are currently attracting a great deal of attention, with hundreds of related patents recently filed and or issued. However, as long ago as January 1996, Kodak was issued a patent for producing an organic LED array on an ultra thin substrate. These examples demonstrate how, despite the delays associated with pendency, patents can provide insights into cutting edge technological developments.

To identify hotspot patents empirically, we used two criteria. First, we first selected all US utility patents[2] cited by at least ten patents issued between January 2001 and August 2002. As shown in Table 1, these patents are among the 5% most highly cited patents during this period. Hence they have a strong impact on emerging technology.

Table 1 – Distribution of patents according to number of citations received from patents issued between 1/1/01 and 8/31/02

Number of citations from patents issued 1/1/01 – 8/31/02	Number of Patents	Percentage of patents (among patents cited at least once)
26+	6,324	0.5%
25+	7,051	0.5%
20+	12,607	0.9%
15+	25,681	1.9%
10+	64,368	5.0%
5+	230,784	17.0%
4+	324,432	24.0%
3+	480,277	36.0%
2+	763,118	57.0%
1+	1,335,280	100.0%

The second filter we used was designed to focus our analysis on patents that earn a large fraction of their citations from recent patents, rather than from older patents. To qualify as hotspot patents, patents issued after 1995 must receive at least 50% of their citations from patents issued between January 2001 and August 2002. For older patents this threshold is reduced. The minimum threshold is 25% for a patent issued in 1975. The 25% minimum threshold was selected empirically. We examined a sample of citation classics - older patents receiving over 100 citations from later patents - and determined a threshold that would eliminate them from the list of hotspot patents.

To identify hotspot patents more precisely, we used a proportional cutoff of P% of citations where P = (25/21)*year - 2326.19 (using this formula, P = 50 when year = 1996,

[2] Utility patents are regular invention patents, rather than design patents, plant patents, or re-issue patents

and P = 25 when year = 1975). As an example, a 1975 patent cited by 300 subsequent patents must receive at least 75 of these citations from patents issued between January 2001 and August 2002 to be considered a hot-spot patent. Meanwhile, a 1996 patent receiving 50 citations must receive 25 of these citations from patents issued over this same 20-month period.

Using these two criteria to filter the patents, we identified a total of 16,451 hot-spot patents issued between 1975 and 1999. A database containing these patents was constructed for a project for the National Institute of Science and Technology Advanced Technology Program (NIST-ATP). Many of the patents in this database were issued in the mid to late 1990s. However, there are also several hundred hotspot patents issued in the 1970s that are currently being cited frequently, having been relatively ignored for most of their history.

Hotspot patents are distributed across a wide range of technology areas. To determine the technology areas where there are concentrations of hotspot patents, we split these patents according to the Patent Office Classification (POC) assigned to them by the US Patent Office. The POC reflects the patent examiner's understanding of the major technology areas covered by a particular patent. The examiner often assigns numerous POCs to a patent, as it covers a variety of technology areas. To simplify our analysis, we focused on the first POC assigned to each patent. This primary POC is the major technology area covered by the patent in the opinion of the patent examiner.

Table 2 shows the ten POCs with the largest number of hotspot patents. This list reflects the range of technology areas that are particularly active in recent times, such that earlier patents in these areas are being cited frequently.

Table 2 – US Patent Office Classifications with largest number of hotspot patents

Patent Office Classification	Description	Number of Hotspot Patents
438	Semiconductors	892
606	Surgical Instruments	519
257	Transistors and Diodes	509
600	Surgery	481
709	Multi-Computer Coordinating	456
370	Multiplex Communications	427
345	Computer Graphics Processing	364
435	Molecular and Micro Biology	362
424	Drugs & Treatment Compositions	320
361	Electrical Systems and Devices	312

The list is largely as expected, in that most of the technologies in the list are widely regarded as important drivers of technological developments. They include semiconductors, computer networking, telecommunications, microbiology (which forms the basis for the biotechnology industry) and advances in surgical instruments and procedures. The fact that the list contains such important technologies helps to validate the hotspot technique. If the list of technologies had been more obscure, this would raise concerns that the hotspot methodology does not highlight important areas of technological development.

Identifying Papers funded by Government Agencies

The section above describes a method for identifying hotspot patents - patents whose impact on recent technological developments is particularly strong. This section describes the techniques we used to link these patents to publicly funded science. These links enable us to examine the question of whether patents linked to public science are more or less likely to become hotspot patents.

To examine this question, we focused on citation links between patents and scientific literature. As discussed earlier in this paper, when a patent is applied for, its inventor must cite all of the previous technology upon which it builds. This technology may be in the form of earlier patents, but it may also include other materials, especially papers published in scientific journals. Previous research has shown that, in recent years, patents have cited increasing numbers of scientific papers as prior art (Narin et al. 1997). Hence, by examining the citations from patents to scientific papers, we are able to identify the scientific research upon which particular patents have built.

Public organizations, such as funding bodies and government agencies, support many scientific research efforts. It is customary for the papers that result from these research efforts to acknowledge this funding. We can therefore determine which scientific papers are supported by public funding, provided this funding is acknowledged. Our analysis is based on studying the citations from hotspot patents to scientific papers funded by four US government agencies – Department of Energy (DOE), National Aeronautics & Space Administration (NASA), National Institutes of Health (NIH) and National Science Foundation (NSF). Our purpose was to determine whether patents that cite research funded by these agencies are more likely to become hotspot patents.

The data for our analysis were taken from CHI's funding acknowledgements database. This database contains funding acknowledgements for scientific papers that meet two criteria. First, they must have at least one author based in the USA. Second, within ten years of their publication, they must be cited by at least one patent granted by the US Patent & Trademark Office.

There are 227,639 unique papers in CHI's funding database. These represent all papers with at least one US author that are cited by at least one US patent in the subsequent ten years. Out of these 227,639 papers, 84,227 papers were not found in CHI's search of journals, or they reported no funding information. A further 1,851 papers reported funding sources that were unknown and could not be classified. Therefore, 141,561 papers remained that acknowledge funding from a classifiable source. Out of these 141,561 funded papers, we determined that 90,757 (64%) are funded by NASA, NSF, NIH or DOE. These papers form the basis for our analysis.

It should be noted that the data are based on funding acknowledgements, not institutional affiliations. As a result, intramural papers are not included in the analysis. For example, if a scientist at an NIH laboratory authors a scientific paper, and names NIH as the author institution, this will not be included in the analysis based on this author affiliation. However, if NIH provides funding support for extramural research, carried out at an institution other than NIH, this will be included in our analysis. Focusing solely on funding to identify papers may provide an incomplete picture of the role of different government agencies. However, it does provide uniformity across agencies, since some support both intramural and extramural funding, while others provide only extramural support.

Results

This paper examines the question of whether patents that cite scientific papers supported by public funding have a higher or lower probability of becoming hotspot patents. If the probability is higher, this suggests that public funding of science often provides an important foundation for influential technological developments. If the probability is the same or lower, this suggests that the impact of publicly funded science is less pronounced.

Our analysis concentrates on hotspot patents issued between 1995 and 1999 since, as shown in Table 3, this time period contains the largest number of such patents.

Table 3 – Number of Hotspot Patents Issued by Time Period

Time Period	Number of Hotspot Patents
1975-1979	528
1980-1984	517
1985-1989	950
1990-1994	2,346
1995-1999	11,395

Out of the 624,275 patents issued between 1995 and 1999, 11,395 (1.8%) are hotspot patents. This percentage forms the benchmark for this study. If we take any subset of patents, we would expect approximately 1.8% of them to be hotspot patents. For example, if we take the subset of patents that cite papers funded by government agencies, we would expect 1.8% of these patents to be hotspot patents.

We matched the list of all patents granted between 1995-99 against our database of paper funding acknowledgements. There are 34,479 patents granted in this period that cite a paper funded by DOE, NASA, NIH or NSF. Out of these 34,479 patents, 1,101 are hotspot patents. Hence 3.2% (1,101/34,479) of patents that cite a scientific paper funded by at least one of the four government agencies are hotspot patents. This is almost twice as high as the 1.8% benchmark for all patents. A Chi-square test revealed that the percentage is significantly higher (at the 1% level) than the overall benchmark. This suggests that patents that build on publicly funded science have an increased likelihood of becoming hotspot patents, and thus have a strong impact on later technological developments.

Table 4 shows the ten Patent Office Classifications (POCs) with the largest number of hotspot patents that cite agency funded scientific papers.

Table 4 – Patent Office Classifications with largest number of hotspot patents linked to publicly funded scientific papers

Patent Office Classification	Description	Number of Hotspot Patents
435	Molecular and Micro Biology	205
514	Drugs & Treatment Compositions	135
600	Surgery (Diagnostics)	67
438	Semiconductors	42
536	Organic Compounds	31
606	Surgical Instruments	26
707	Database Management	25
257	Transistors and Diodes	24
709	Multi-Computer Coordinating	22
604	Surgery (Fluid Drawing & Handling)	21

This table can be compared with Table 2, which shows the ten POCs with the most hotspot patents in general. Such a comparison reveals a high degree of overlap between the technologies with the most hotspot patents that cite agency-funded research, and the technologies with the most hotspot patents in general. Seven technologies appear in both of these lists. However, there are differences in the order of the technologies. In particular, life sciences technologies are more prominent among the hotspot patents that cite agency-funded research. The leading POCs in this list are molecular and microbiology, and drugs and treatments.

The difference in the technologies at the head of the two lists can be partly explained by the focus of the funding agencies, particularly NIH, which is the largest of them. NIH funding is given almost entirely to life sciences researchers, so patents linked to NIH funded research are likely to describe life science technologies. Although the other agencies focus on life sciences to a lesser extent, the sheer size of NIH funding tends to shift the focus of the analysis towards the life sciences.

A second factor that may contribute to the emphasis on life science technologies in Table 4 is the extent to which patents in different industries cite scientific research. In particular, patents in the life sciences tend to cite large numbers of scientific papers. CHI's Tech-Line database, which contains the patents of the 1,700 leading patenting organizations worldwide, splits patents into technology categories based on their patent office classification. This database shows that biotechnology patents cite an average of 29 scientific papers each, while pharmaceuticals patents cite around 14 papers each. These numbers can be contrasted with the much lower numbers of scientific papers cited by patents in other technologies. In semiconductors and in telecommunications, patents cite an average of 1.5 scientific papers each. Even lower citation rates can be found in automotive and machinery patents, where the average is less than one scientific paper cited for every four patents.

The high number of citations to scientific papers in life science patents occurs because many important advances in the life sciences are made by academics. As such, they are often reported in scientific papers rather than patents. Patent inventors have to cite these papers in order to detail fully the state of the art in a specific life sciences technology. In industries such as the automotive industry, technical advances tend to occur more frequently in commercial, rather than academic, organizations. As a result patent inventors tend to cite previous patents, rather than scientific papers.

Among hotspot patents, those in life sciences are therefore likely to cite greater numbers of scientific papers. As a result, these patents are more likely to be linked through citations to any subset of scientific papers, such as the set of papers funded by government agencies. If we add the focus of NIH on life sciences research, the analysis presented here is skewed somewhat towards life science patents. However, this effect should not be overstated, since half of the ten technologies listed in Table 4 are not concerned with the life sciences.

The question could also be raised as to whether the emphasis of our analysis on life sciences patents affects our finding that patents citing agency-funded research are more likely to become hotspot patents. In particular, if life sciences patents are over-represented among hotspot patents, our results could be misleading. In that situation, our analysis may suggest that patents are more likely to become hotspot patents because they are linked to agency-funded research. However, the underlying cause may be that life science patents (which, as outlined above, are more likely to cite scientific research) are more likely in general to become hotspot patents.

To examine this question, we again used the Tech-Line technology classifications. We identified the technology classification for all patents issued between 1995 and 1999. We found that out of these 624,275 patents, 33,442 are in biotechnology or pharmaceuticals, the two main life sciences technologies in the database. Hence, 5.4% of all patents issued in this period are life sciences patents. We then identified the technology category of the hotspot patents, and found that only 765 out of 16,451 (4.7%) of these patents are in biotechnology or pharmaceuticals. Hence, life sciences patents in general do not have an increased likelihood in general of becoming hotspot patents. This means that, while the analysis presented here is skewed towards life sciences patents, this does not invalidate the finding that patents citing agency-funded scientific papers are more likely to become hotspot patents.

Links to Individual Agencies

Having determined that patents linked to publicly funded scientific papers are more likely to become hotspot patents, we then examined the question of whether this finding differs across funding agencies. To look at this question, we examined the links between patents and papers funded by each of the four government agencies individually. The results of this analysis are summarized in Table 5.

Table 5 – Percentage of patents that cite scientific papers funded by government agencies that become hotspot patents

Agency Funding Scientific Papers	Number of Patents Citing Funded Papers	Number of Citing Patents that are Hotspot Patents	Percentage of Citing Patents that are Hotspot Patents
DOE	6,046	302	5.0%
NSF	14,840	639	4.3%
NASA	1,804	72	4.0%
NIH	25,606	648	2.5%

This table shows that, in total, 6,046 patents issued between 1995 and 1999 cite a paper funded by DOE. Out of these patents, 302 are hotspot patents. Hence 5% of patents that cite DOE research are hotspot patents. This is almost three times as high as the overall benchmark (as noted earlier, 1.8% of all patents are hotspot patents). It is also 50% higher than the overall figure for patents that cite papers funded by any of the four government agencies examined in this analysis.

The table also shows that patents linked to NSF research have a higher than expected likelihood (4.3%) of becoming hotspot patents. The same is true for patents linked to NASA patents. Out of these patents, 4% become hotspot patents. The percentage of patents linked to NIH research that become hotspot patents is lower at 2.5%. However, this percentage is still higher than the overall 1.8% benchmark for all patents. Chi-square tests revealed that all of these percentages were significantly higher than expected at the 1% level.

This finding suggests that there are differences in the propensity for patents to become hotspot patents, depending upon the agency to whose research they are linked. In particular, patents that build in some way on DOE-funded science and, to a slightly lesser extent, NSF and NASA funded science, have a greater chance of becoming hotspot patents. As such, these patents are more likely to influence future technological developments. Patents linked to NIH research also have a greater chance of becoming hotspot patents than patents with no links to agency funded research, but to a lesser extent than patents linked to DOE, NSF and NASA funded science.

In order to examine these results in more detail, we identified the technologies where hotspot patents have particularly strong links to research funded by each of the four agencies. We again used patent office classifications (POCs) to identify these technologies, and the results are shown in Table 6.

Table 6 – Patent Office Classifications with the largest number of hotspot patents citing papers funded by different government agencies

POC – Description	POC – Description
DOE	**NSF**
435 – Molecular/Micro Biology	435 – Molecular/Micro Biology
438 – Semiconductors	424 – Drugs/Body Treating Compositions
204 – Electrical and Wave Energy	438 – Semiconductors
536 – Organic Compounds	707 – Databases
382 – Image Analysis	709 – Multi-Computer Coordination
NASA	**NIH**
435 – Molecular/Micro Biology	435 – Molecular/Micro Biology
382 – Image Analysis	424 – Drugs/Body Treating Compositions
118 – Coatings	600 – Surgery (diagnostics)
424 – Drugs/Body Treating Compositions	536 – Organic Compounds
370 – Multiplex Communications	606 – Surgery (instruments)

This table shows the five POCs with the largest number of hotspot patents linked to research funded by each of the four agencies. Molecular biology and microbiology, which represent the center of the biotechnology industry, head the list for each agency. This reflects the earlier argument that life science patents are emphasized by the analysis, because they cite large numbers of scientific papers.

Looking beyond the biotechnology area, Table 6 reflects the different emphasis of each of the four agencies. NIH's influence is almost entirely in the life sciences, as one would expect. The other agencies have an influence in a broader range of technologies. DOE and NSF both fund research linked to semiconductor research. However, while the remainder of the DOE list covers electrical energy, chemistry and image analysis, research funded by NSF is more influential in computer networking and databases. NASA's list contains technologies that appear in other agencies' lists, notably image analysis and drugs, but also technologies that do not appear elsewhere, particularly coatings and multiplex communications.

Multiple Agencies

We examined the question of whether diversity of scientific funding has any impact on the results. To do this, we analyzed whether patents that cite papers funded by more than one government agency are more likely to become hotspot patents. The results for patents citing papers funded by two agencies did not differ much from the figure for patents citing papers funded by a single agency. 3.3% (276 out of 8434) of the patents that cite a paper funded by two agencies become hotspot patents, compared to 3.2% for patents citing any agency-funded paper.

We then looked at papers with greater diversity of funding – those funded by at least three out of the four agencies. We found that 6.6% (29 out of 441) of the patents that cite these papers become hotspot patents. Although the number of patents in this group is relatively small, a Chi-square test revealed that patents that cite a paper funded by at least three agencies are significantly more likely (at the 1% level) to become hotspot patents.

Patents that build on scientific papers with this highly diverse funding are therefore over three times more likely than expected to become hotspot patents. It is possible that papers that attract funding from diverse sources represent particularly important and innovative ideas. They may also represent ideas that have broad applications across a range of technology areas. As such, they may be more likely to form the foundation for a series of technological developments than scientific ideas with a narrower, less innovative focus.

Next Generation Patents

The analysis presented to this point has focused on hotspot patents – older patents that have a strong impact on recent technological developments. This analysis provides insights into the extent to which publicly funded research provides the foundation for these hotspot technologies. However, it does not highlight how publicly funded science forms the foundation for the recent developments building on these hotspot technologies. In order to examine this issue, we analyzed what we describe as 'next generation' patents.

Next generation patents are patents issued between January 2001 and August 2002 that cite at least one hotspot patent. As such, they represent the successor technologies that are building on hotspot patents. Out of the 274,310 patents issued between January 2001 and August 2002, 66,216 are next generation patents. Hence 24.1% of patents issued in this period are next generation patents.

The percentage of next generation patents is much higher than the percentage of hotspot patents. This is because hotspot patents tend to be highly cited, often by recent patents. For example, if a hotspot patent is cited by twenty patents issued between January 2001 and August 2002, this results in twenty next generation patents for a single hotspot patent.

Next generation patents do not necessarily represent important technological discoveries, as they qualify simply by citing a hotspot patent. However, this does not mean that there is no interest in examining them. By building on hotspot patents, they are likely to be advancing the state of the art in a heavily researched technology area. As such, by evaluating the extent to which next generation patents are building on publicly funded scientific research, we can analyze how this research is contributing to the continuing development of cutting edge technologies.

To examine the links between next generation patents and publicly funded scientific research, we used the same approach as described earlier in the analysis of hotspot patents. Hence, we identified all patents issued between January 2001 and February 2002 that cite a scientific paper funded by DOE, NASA, NIH or NSF. We then determined what percentage of these citing patents are next generation patents. The results of this analysis can be seen in Table 7.

Table 7 – Percentage of patents that cite scientific papers funded by government agencies that become next generation patents

Agency Funding Scientific Papers	Number of Patents Citing Funded Papers	Number of Citing Patents that are Next Generation Patents	Percentage of Citing Patents that are Next Generation Patents
DOE	2164	1120	51.8%
NASA	424	198	46.7%
NSF	4710	1995	42.4%
NIH	9044	2702	29.9%
Any of 4 Agencies	11579	3966	34.3%

This table shows that between January 2001 and August 2002, over 34% of papers citing a paper funded by one of the four agencies is a next generation patent. This percentage increases to 51% for patents citing DOE funded papers, 46% for patents citing NASA funded papers, and 42% for patents citing NSF funded papers. The percentage is much lower, at 30%, for patents citing NIH funded papers. However, this is still higher than the overall percentage of patents (24%) that are next generation patents.

This finding suggests that, not only are patents that cite publicly funded scientific research more likely to be hotspot patents, they are also more likely to be in the next generation that builds on these hotspots. Hence, publicly funded science appears to form an important foundation for generations of technological developments.

Conclusions

This paper introduces a novel method for identifying patents whose impact on the most recent technological developments is particularly strong. These patents are defined as hotspot patents. In this paper, we examine the citation links between these hotspot patents and scientific papers funded by government agencies. Our analysis reveals that patents that cite scientific papers funded by government agencies are more likely to become hotspot patents. This suggests that funding of scientific research by government agencies provides an important foundation for many high impact technological developments. This foundation is particularly important in fast moving, highly innovative industries, including biotechnology, semiconductors, computing and communications.

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