An Empirical Study of the Anticommons Effect on Public vs. Private Researchers

Serena S. Lam[†]

Professor Paul Ellickson, Faculty Adviser

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Duke University
Durham, North Carolina
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[†] serenaminlam@gmail.com

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Abstract

The "anticommons effect" is a recently coined term to describe the phenomenon of stifled research and innovation in the biomedical research arena due to the growing number of overlapping patents in particular domains. Murray and Stern (2005) was the first to devise a novel strategy to quantify this effect by looking at the citation trend of papers with patented findings compared to that of non-patented ones published in *Nature Biotechnology*. This study continues this vein of research by looking at the differential anticommons effect on public vs. private sector researchers by dividing the citations of the articles used in Murray and Stern (2005) into public and private sector citations, and running a negative binomial fixed effects regression through both groups. Similarly, the citations were also divided into high vs. low tier journals, US vs. foreign authors, and scholarly vs. non-scholarly citations for further analysis. It was found that public sector citations dropped by 19.53% for patented articles compared to non-patented papers, while no such effect was found for private sector citations, suggesting that the anticommons effect is salient primarily for public sector researchers. A significant anticommons effect was also found for low tier journal citations (22.25%), US (15.96%) and foreign authored citations (21.72%), and for scholarly citations (17.26%) as measured by the average decrease in yearly citation rates for patented papers.

I. Introduction

With the advent of biotechnology and the dawn of the genetic era, mounting debate has developed on the appropriateness of the U.S. patent system that was originally designed during the mechanical age of inventions for the changing landscape of applied science and biotechnology research. A notable example in recent headline news of this controversy is the three patents on human embryonic stem cells fundamental to this field of research that have all been granted to University of Wisconsin scientist, James A. Thomson (Pollack, 2006). These patents were granted for human embryonic stem cell lines whose distribution is handled by the Wisconsin Alumni Research Foundation (WARF). WARF has exclusive rights to these embryonic stem cell lines and are legally able to prevent anyone from making, using, or selling them in the United States until 2015 (Loring and Campbell, 2006). Currently, WARF provides academic researchers with free licenses and charges $500 for the cells while companies are charged between $75,000 and $400,000 (Pollack, 2006). In addition, the private company Geron Corporation received broad exclusive commercial rights to heart, nerve, and pancreatic cells derived from the human embryonic stem cells that they helped fund, meaning that any company developing therapies in these areas must negotiate fees and pay royalties to them whether or not they plan on doing basic or commercial research (Loring and Campbell, 2006). A California consumer group, Foundation for Taxpayer and Consumer Rights, as well as other stem cell scientists have complained that these broad patents have impeded subsequent embryonic stem cell research, even causing some operations to move offshore where these patents are not applicable (Pollack, 2006). This inhibiting effect on research by "patent-thickets" can be attributed to a phenomenon known as the "tragedy of the anticommons."

The "tragedy of the anticommons" was first coined by Heller and Eisenberg (1998) and has been used predominantly to describe the overlapping of intellectual property rights (IPR) in biotechnology research and the subsequent barriers to research it poses. This is a growing concern given the unprecedented six fold increase in the number of patents granted by the USPTO in the last 20 years, from about 2,000 in 1982 to about 6,000 in 2002 (OECD Statistics, 2006). The tragedy of the anticommons is related to the more widely known tragedy of the commons. In the classic example of the tragedy of the commons, a shared resource is overused due to the inability of each shareholder to exclude one another's use (e.g. a common pasture is overgrazed by sheepherders). For the tragedy of the anticommons, a resource becomes underused when shareholders each have the right to exclude each other from usage, resulting in no one having the effective privilege of use (Heller, 1998).

The patent thickets in areas of biotechnology as exhibited in embryonic stem cell research have caused some to worry about an "anticommons" effect. In the case of patenting in biotechnology research, the more patent holders there are for a specific area of knowledge, the more costly it is for a researcher to obtain all the licenses necessary to conduct follow up research. Although there has been much talk about a tragedy of the anticommons effect in biotechnology research since its conception by Heller and Eisenberg in 1998, little empirical evidence has been gathered to support and quantify its existence in a systematic method. In fact, there has only been one study to date that attempts this. The lack of studies is a result of the difficulty in finding an accurate method by which to measure the anticommons effect. To this end, Murray and Stern (2005) devised a novel method of estimating the under-usage of patented information by studying what is known as patent-paper pairs (Murray, 2002). A patent-paper pair occurs when an author publishes both a paper and files for a patent on the same piece of knowledge (Murray and Stern, 2005). There typically exists a time lag between the publication of an article and the official granting of the corresponding patent of about 37.5 months. If a patent truly inhibits follow up research, then this should translate into fewer citations after the granting of a patent due to the elimination of researchers who are deterred by the economic costs of obtaining the requisite licenses. Therefore, by studying the citation trends of patent-paper pairs in their pre- and post-patent phases and comparing it to the citation trends of non-patented papers, Murray and Stern (2005) were able to quantify the anticommons effect. In other words, they were able to quantify the severity of the barriers to research imposed by the installation of a patent. Murray and Stern (2005) found that there was a modest, but significant anticommons effect that occurred in their sample of about 9 to 17%.

This paper provides further understanding to the issue by using similar strategies as Murray and Stern (2005) to quantify the anticommons effect for particular groups of researchers. The primary objective of this paper is to determine if the anticommons effect disproportionately affects follow-up research done by the public sector as compared to the private sector. Since public sector researchers do not usually have access to the same amount of financial resources as private sector researchers, there is reason to believe that perhaps public sector researchers are more deterred from follow-up research on a patented area of knowledge than their private sector counterparts (due to inability to pay for access to patented material). Because basic research (as opposed to applied) is done primarily in the public sector, a finding that public researchers are disproportionately affected by the anticommons effect may indicate that basic research is being stymied, a concern that may warrant intervention from the policy arena (i.e. exempting publicly funded science researchers from having to pay licensing fees).

This analysis is done by dividing the citations of patent paper pairs into private and public sector researchers and running a fixed effects negative binomial regression to determine the effect of a patent grant on the number of subsequent yearly citations. This study finds that the anticommons effect indeed primarily acts on public sector researchers at a statistically significant rate of -19.53%. Furthermore, this study finds that there is no evidence for an anticommons effect on private sector researchers. Similarly, there is found to be a significant anticommons effect for low tier journal citations at -22.25%, scholarly citations at -17.26%, and non-US authored citations at -21.72%.

In addition to quantifying the anticommons effect for public and private sector researchers, this study also looks at the differential anticommons effect for high impact vs. low impact research, US vs. foreign authored research, and scholarly vs. non-scholarly work.

This paper accomplishes the stated end by first providing a literature review of relevant research on the anticommons effect in Section II. This section is followed by a description of the theory behind the anticommons effect and its role in public vs. private sector research, including an economic model of the anticommons effect using the classical Cournot-Nash Duopoly framework in Section III. Section IV describes the data used in the analysis, while Section V contains the empirical analysis and results. Finally, I conclude and discuss the main findings of this paper in Section VI.

II. Literature Review

The following literature review puts the issue of the anticommons effect in scientific research into perspective and describes how this study will add to the ongoing debate by discussing the stages in the development of the anticommons theory. This is done by first describing its conception in the law literature, the subsequent grounding in economic modeling, and most recently, quantitative evidence of its existence through empirical testing. This study then adds to the progress of the anticommons theory by providing results that have important implications in the policymaking arena.

Heller (1998) was the first to conceive and apply "the tragedy of the anticommons" to the transition of socialized markets to privatized ones. In his example, storefronts in Moscow remained empty despite there being rows of metal kiosks brimming full of wares just outside the empty stores. Venders were not renting the stores due to the cost and hassle of obtaining all the consents and agreements from the multiple government agencies and private parties that each held rights over the same store spaces. In this historical case, even though there was a high demand for store space, none of it was being used because of the problem of overlapping property rights—the heart of the tragedy of the anticommons.

Heller and Eisenberg (1998) soon after published an article extending this effect to the patenting situation for biomedical research. They discuss the ramifications of the transition of research done under a commons model where federally sponsored upstream research is widely and freely distributed for use in downstream research and innovation, to a privatized model where even upstream research conducted at the federal and academic levels is encouraged to be patented. This was a result of the 1980 Bayh-Dole Act in which academic and non-profits were allowed to patent all eligible federally sponsored research according to USPTO guidelines (Thursby et al., 2003; Boettiger et al., 2006).

Written from a legal perspective, the anticommons effect was not described in a formal economic model until an analysis by Buchanan and Yoon (2000), which showed symmetry between the geometric-algebraic framework of the tragedy of the commons to that of the anticommons. Although these studies set up an important foundation to the theory of the anticommons effect, none of them provided any direct evidence through the collection of hard data. Since then, there has only been one empirical study done by Murray and Stern (2005) that tries to prove the existence of the anticommons effect in the field of biotechnology.

It is likely that an empirical study was not done until recently due to the complex nature of quantifying the anticommons effect. Murray and Stern (2005) was able to devise a strategy involving the comparison of citation patterns of patent-pair papers (papers that publish findings that are granted patents) to that of comparable quality papers without patented material. Murray and Stern (2005) took advantage of the lag time between publishing a paper and receiving the patent to look at how citation rates changed in the pre-granting of the patent versus the post-granting of the patent in the high impact factor journal *Nature Biotechnology* from 1997-1999. The difference in citation rates of a paper before and after patent grant acts as a proxy of the barriers to subsequent research posed by a patent. Murray and Stern (2005) used a differences-in-differences estimator for 169 patent-paper pairs plus a control group of non-patented papers. They found evidence for a modest anticommons effect with a citation drop rate between 9 and 17% after granting of a patent.

This analysis of paper-patent pairs is not a novel method. It has been utilized extensively in research on the effect of patenting by university researchers and its subsequent effect on their output measured by the number of publications produced following publication of the patent-pair (Stephan et al., 2005; Agrawal et al., 2002; Azoulay et al., 2005). However, this method is novel in its use as an indicator of the presence of research barriers due to the enforcement of a patent.

This study builds on Murray and Stern's (2005) work by subdividing a sample of the citations of their data set into public and private sector researchers. In doing so, it is possible to determine whether one sector is more adversely affected by the anticommons effect than the other. Since the public sector has less financial resources than their private counterparts, it is expected and is indeed shown that there is a much greater anticommons effect as measured by yearly citations rates for public sector researchers.

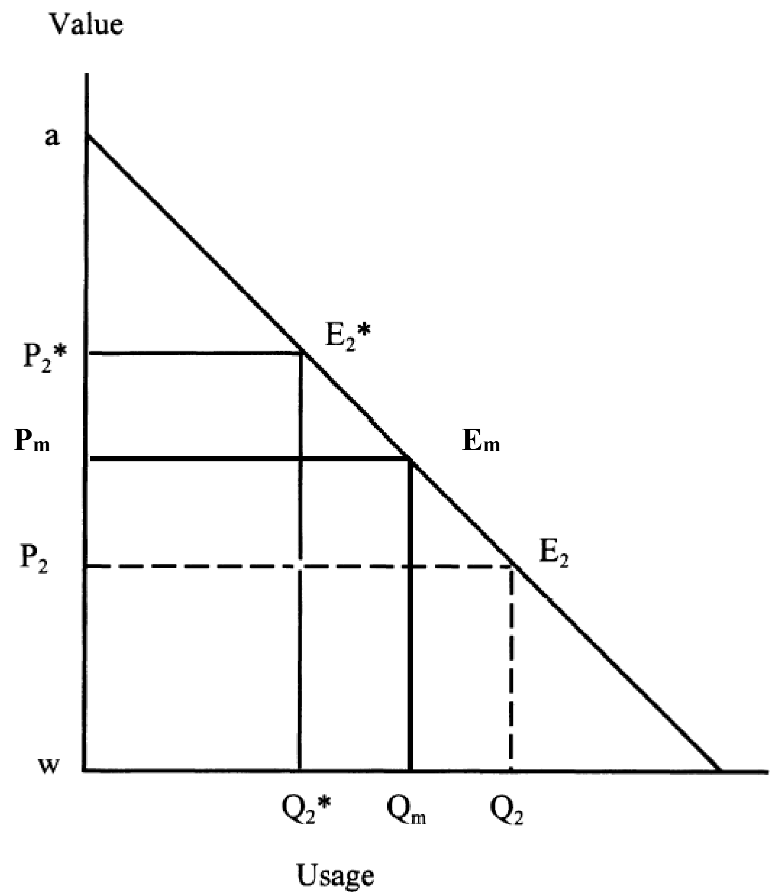
III. Anticommons Theory

This section will ground the anticommons effect in economic theory by first describing the Buchanan and Yoon (2000) model. Then, a discussion of the Stokes' (1997) basic vs. applied research model will motivate this study's focus on the anticommons effect as it is manifested in the public vs. private sectors.

The Anticommons Effect—The Model

In the case of the tragedy of the commons, a common resource becomes overused when multiple individuals have the privilege of use and none are able to constrict each other's usage (e.g. the overgrazed common pasture shared by multiple sheepherders). In contrast, the tragedy of the anticommons occurs when a resource with multiple owners, each with the ability to exclude one another, becomes underused (Parisi et al., 2004).

Buchanan and Yoon (2000) use a stylized case to illustrate the symmetric nature of these tragedies. In their example, a parking lot with two owners, one issuing red permits and the other issuing green ones, can only be used when both green and red permits are obtained. The value of the parking lot is inversely related to the number of users. The following figure is a graph modified from Buchanan and Yoon (2000) of the average marginal value of using the parking lot as a function of the number of its users.



In the situation of a single owner of the parking lot, rents can be maximized by restricting usage of the parking lot to the level Q_m and pricing at a profit-maximizing price P_m. With two owners of the parking lot each selling permits, the number of users will drop to Q_2^* below the profit-maximizing Q_m at a price above P_m at P_2^*. The two owners will then share the rent represented by the area $P_2^*E_2^*Q_2^*w$ (an area smaller than the profit-maximizing area for a single owner $P_mE_mQ_mw$)[1]. This result is seen by calculating the price at which the first owner will sell his green permits given that the second owner simultaneously charges for his red permits.

Besides this graphical interpretation, the anticommons effect can be more quantitatively demonstrated using a Cournot-Nash duopoly framework:

Let Q be the level of usage of the parking lot and P_1 be the price of a green permit and P_2 be the price of a red permit. With a and b as constants, the relationship between Q, P_1, and P_2 is as follows:

$$P_1 + P_2 = a - bQ.$$

When each owner maximizes his rent by setting his ticket price, the first owner chooses P_1 so as to

$$\max P_1Q = P_1(a - P_1 - P_2)/b.$$

The first-order condition for maximization then becomes:

$$(a - P_1 - P_2)/b - P_1/b = 0.$$

P_1 can be expressed as a function of P_2 and vice-versa:

$$P_1 = a/2 - P_2/2$$

$$P_2 = a/2 - P_1/2.$$

The two equations are solved to get the Nash equilibrium outcome:

$$P_1^* = P_2^* = a/3.$$

Generalizing to n number of owners/excluders,

Price: $P_n^* = a/(n+1)$

Usage Levels: $Q(n) = Q_0/(n+1) = (a/b)/(n+1)$

[1] The tragedy of the commons effect occurs when there is an overusage of the common property and is shown in dotted lines. It can thus be seen how the rent area for the tragedy of the anticommons effect is the same as the rent area for the tragedy of the commons effect as represented by $P_2E_2Q_2w$.

Total Rent: $TR(n) = n(a^2/b)/(n+1)^2$.

The equation for Q, or the usage level, can be used to assay the anticommons effect, which fundamentally is about a net decline in the usage of a resource. From the above equation for Q, it can be seen that the usage level Q approaches 0 as the number of excluders grows infinitely large. In other words, the resource becomes underused as its privilege of use is granted to multiple owners—the tragedy of the anticommons at work.

Now that the anticommons effect has been modeled theoretically, motivation for measuring its impact on biotechnology research and its differential effect on public and private sector researchers is warranted.

The Anticommons Effect in Public vs. Private Research

Growing interest in the anticommons effect has developed in recent years in part due to the changing landscape of science research. What used to be a clear delineation between basic research and applied research has now become a much more blurred boundary, particularly in the areas of biotechnology and biomedical research. As traditionally defined, basic research is conducted purely to expand the scientific knowledge base while applied research is focused on knowledge that will derive an immediate practical use. As each territory has encroached on the other in fields like biotechnology and biomedical research, it has become more and more common for research to be both fundamental and practical in nature, as illustrated by the rising occurrences of patent-paper pairs (Murray and Stern, 2005). Stokes (1997) captured this phenomenon in his model of science research:

The Stokes Model

	Consideration of Use?		
		NO	YES
Quest for Fundamental Understanding?	NO		Pure Applied Research
	YES	Pure Basic Research	Use-inspired/translational Basic Research

Basic science research has traditionally operated under "Open Science" norms (similar to the open source norm of sharing/editing programs in computer science) whereby knowledge is distributed freely and research is done cumulatively on a piece of work. Public researchers of basic science perform under an incentive structure involving prestige gained from publication in high impact journals (Murray and Stern, 2005; Shreeves, 2004). On the other side, private researchers operate under incentive structures involving commercial gains accrued by the granting of a patent and the ability to restrict access to their contribution. Because norms have been established for the dissemination of knowledge in each of these territories, it becomes problematic when a piece of knowledge falls under both umbrellas. Now that a researcher can simultaneously publish and apply for a patent on his or her finding, there is reason to believe that the restrictive nature of patents will carry-over into this area of research that is both fundamental and applied in nature. What was first meant to encourage innovation and entrepreneurial activity in the commercial research sector may now cause a stifling of research done at all levels—basic to applied, as illustrated in the example of the patents on seminal technology in human embryonic stem cell research.

Furthermore, the anti-commons effect may disproportionately affect public sector researchers more so than private sector researchers due to comparatively lower access to financial resources. This is a matter of particular concern since public sector researchers are more likely to conduct basic research than private sector researchers, an endeavor that is fundamental to the advancement of science. Recognizing this, organizations like the National Institutes of Health (NIH) on occasion have interfered on behalf of academic researchers to negotiate lowered access rates to patented technology as in the case of the human embryonic stem cell lines (it now costs academic researchers $500 to use WARF's stem cell lines while commercial researchers are charged anywhere between $75,000 and $400,000 for access regardless of the type of research being pursued).

A similar case that caused a stir in the science community regarding the possibility of public sector researchers being subjected to undue monetary barriers to research was the sequencing of the human genome by the private company Celera Genomics. According to their initial business model, they were to charge both academic and commercial researchers alike to access their comprehensive database containing the entire sequence of the human genome, clearly a seminal technology that cannot be bypassed when conducting research in human genetics (Shreeves, 2004). Fortunately, the existence of the publicly funded Human Genome Project, which was furiously competing with Celera to complete the sequencing of the human genome for unrestricted public access, gave the academic community leverage in negotiating contracts with Celera. During the race to sequence the human genome, Celera continually tried to assuage the community's concern that they would act as an unchecked monopoly and charge exorbitant prices to maximize their profits at the expense of public welfare. Without the publicly funded project, Celera's business model would likely still exist today (it has since become a pharmaceutical company, a more profitable endeavor than contracting out access to the human genome which can now be accessed without charge courtesy of the publicly funded Human Genome Project) (Shreeves, 2004).

This particular concern in the research community of the public sector researchers' right to fairly access patented material may then be justified if it is shown that the anticommons effect disproportionately affects them. This will be shown if the citations belonging to public sector researchers decreases more than that of private sector researchers after the granting of a patent as compared to citation trends in articles without patents. The remainder of the paper will be dedicated to empirically answering this question.

IV. Data

In determining whether there is a greater anticommons effect on subsequent public versus private sector research, this study uses the data set collected by Murray and Stern (2005), which includes a sample of patented and non-patented articles (used in the 2005 Murray and Stern study) and their forward citations[2]. As the leading journal for biotechnology, *Nature Biotechnology* was chosen as the source of the sample of articles because it would most likely contain the highest proportion of patent-paper pairs. As noted by Murray and Stern (2005), the journal's mission statement is to publish high quality research with potential applications to biotechnology. For the purposes of having a more manageable dataset and due to issues of data completeness, a subset of the original 340 articles were pulled from the 2005 Murray and Stern study for the purposes of this analysis.

[2] Forward citations are used in this study to refer to the subsequent papers that cite the original sample of articles studied here. In contrast, backward citations refer to the list of references cited by each article in the sample. Thus, backward citations is a fixed number for each article while forward citations are continually increasing once the article is published.

This study looks at only those articles (of the original 340) that have at least one US and one public sector author[3] published in 1998 and 1999 and their subsequent citations in years 2000 through 2002. This narrows the article population to a sample of 107 articles, 53 of which are patented and 54 of which are non-patented yielding a balanced representation of patent vs. non-patented papers as summarized in Table 3.

It is important to ensure that the articles in this study are similar along the potential for patentability since patentability may be correlated with citation rates. For their analysis, Murray and Stern (2005) took a random sample of their 340 articles to gauge the comparability of the papers. They looked at the level of similarity between the two on multiple variables including patentability, number of U.S. authors, the number and type of institutional affiliations, author age, rank, and gender, and article length. They found that although there were marginally significant differences between the patent-paper pairs and non-patent papers (patented papers tended to have higher rates of citation and those with US affiliated researchers had a higher incidence of a USPTO patent), there were no correlations between patenting and the nature of the research like article length, number of authors, or the number of backward references. In addition, with the help of an experienced patent attorney, Murray and Stern (2005) found that the large majority of the subset (27 out of 34) were considered obviously patentable while the rest had at least some potential. Thus, it can be safe to conclude for this study as well that the articles are all similar in their potential for patentability.

[3] Public sector authored articles were focused on instead of private sector authored because it is possible that researchers expect for private authored articles to be patented. Thus, researchers may avoid using private sector research in both the pre- and post-patent period of the article. If this is the case then the differences-in-differences estimation of this study would not be able to capture the anticommons effect since it takes the difference between the pre- and post- patent period citation levels.

For the subset of 107 articles that this study deals with, there are a total of 5437 forward citations between the years 1999 and 2002 and whose means and standard deviations are listed in Table 2. This data is updated and contains new information about the citations that was not incorporated in the 2005 Murray and Stern study such as private vs. public sector affiliation, US vs. non-US authored citations, journal tier classification, and scholarly vs. non-scholarly works.

By separating citations into public and private sector citations, this study is able to determine the differential anticommons impact on public and private researchers. For each citation, the authors were classified using information garnered from the ISI Web of Science internet resource and if necessary, by identifying institutional affiliations through the citing authors' article. Public sector authors include those that are affiliated with a university or government institution while private authors are those associated with pharmaceutical and biotechnology affiliations. The average number of public sector citations per year is 13.03 and the average for private sector citations is 2.81 (Table 2). Articles with authors affiliated with both private and public sectors were counted in both categories. This situation occurred for 11.13% of the citations, or for 598 of the 5972 citations.

Besides separating along private and public sectors, this data set also divides the citations into two categories—the first "high quality" category consists of citations from journals that are "first tier" or "second tier," a distinction indicating that they are the most prestigious journals in their area of research specialty based on their journal impact factor.[4] Accordingly, the second categorization consists of less prestigious journals that are classified as third or fourth tier. By dividing the citations by the quality of its journal, we are able to

[4] The Journal Impact Factor is an index that scores journals based on the number of times articles in the journal are cited and the number of articles that are published in a certain time period. It is a proxy for the importance of that journal to the particular research field.

look at whether the anticommons effect differentially impacts high quality vs. low quality follow-on research. As reported in Table 2, the average citations per year from high tier journals is 1.27 and 12.62 for those from low tier journals.

This study is able also to look at the impact of the anticommons on US authored researchers vs. foreign researchers. The average citation per year for US authored citations is 2.81 and 5.85 for foreign researchers (Table 2).

Finally, by dividing the citations into reviews and articles and categorizing them as "scholarly citations," and grouping all other types of works not published in peer-reviewed journals, we are able to look at whether the anticommons effect affects scholastic research more than non-scholastic works. The average citation per year for scholarly citations is 13.95 and .47 for non-scholarly citations (Table 2).

Table 1 describes the variables used and their definitions. Table 2 describes the means and standard deviations of the citations. The citations of each article in the set are counted each year beginning at the date of publication until the end of 2002. The average year of publication is 1998.47 while the average patent grant year is 2000.54, which confirms the time lag between publication and patent grant that this study is exploiting.

Table 3 compares the patent-paper pairs with the non-patented group. The average number of forward citations per year for patented papers is 16.46, while it is 12.70 for non-patented papers. This difference (which is also present in the original 340 article population) disappears however, when Murray and Stern (2005) controlled for the number of U.S. authors.

Although this sample is suitable along several parameters (including patentability of papers and the ability to use forward citations as a proxy for follow-on research), the weaknesses must also be considered to understand the limitations of this study. Because the sample set consists of papers published between 1998 and 1999 and tracks citations only up through 2002, there may be a convergence or divergence in the trend in forward citation rates in the long term that we are unable to observe. Furthermore, it takes on average about 3 years after initial publication in order for a patent to be granted, which means that this dataset only tracks the citation rate of patented papers for 3 years in the post-patent period. It is conceivable that the anticommons effect is a delayed effect that does not peak until a later date. Ideally, a dataset consisting of patented papers with expired patents could be analyzed to see if there is a corresponding jump in citation rates after the date of expiration. However, due to the infancy of this area of research and the phenomenon of patenting biotechnology, there are only a handful of such cases.

Finally, it is important to remember that this dataset is narrow and only covers articles published in one journal over a two year time span and tracks the subsequent citations for only 3 years. This limits the scope of any conclusions we may draw from the analysis (i.e. the papers published in *Nature Biotechnology* are not necessarily representative of other areas of research, so these findings may not be applicable to other fields of research subject to IPR).

Table 1
Variables and Definitions

Variable	Definition	Source
Citation-Year Characteristics		
TOTAL FORWARD CITATIONS	Combined Public and Private Sector Forward Citations to Article *j* in Year *t*	SCI
PUB FORWARD $CITATIONS_{jt}$	# of Citing Articles with at least One Public Sector Author to Article *j* in Year *t*	Science Citation Index (SCI); author verification
PRIV FORWARD $CITATIONS_{jt}$	# of Citing Articles with at least One Private Sector Author to Article *j* in Year *t*	SCI; author verification
HIGH TIER JOURNAL $CITATIONS_{jt}$	# of Citing Articles Published in a Tier 1 or Tier 2 Journal to Article *j* in Year *t*	SCI
LOW TIER JOURNAL $CITATIONS_{jt}$	# of Citing Articles Published in a Tier 3 or Tier 4 Journal to Article *j* in Year *t*	SCI
SCHOLARLY $CITATIONS_{jt}$	# of Citations that are Categorized as Reviews or Articles to Article *j* in Year *t*	SCI
NON-SCHOLARLY $CITATIONS_{jt}$	# of Citations that are not Categorized as Reviews or Articles to Article *j* in Year *t*	SCI
US AUTHORED $CITATIONS_{jt}$	# of Citing Articles with at least 1 US Author to Article *j* in Year *t*	SCI
NON-US AUTHORED $CITATIONS_{jt}$	# of Citing Articles without at least 1 US Author to Article *j* in Year *t*	SCI
$YEAR_t$	Year in which FORWARD CITATIONS are received	SCI
AGE_{jt}	YEAR – PUBLICATION YEAR	Nature Biotechnology (NB)
Publication Characteristics		
PUBLICATION $YEAR_j$	Year in which article is published	NB
TOTAL $CITATIONS_j$	# of FORWARD CITATIONS from publication date to 2003	SCI
Patent Characteristics		
$PATENTED_j$	Dummy variable equal to 1 if Article is associated with a patent issued by the USPTO prior to October, 2003	USPTO
GRANT $YEAR_j$	YEAR in which PATENT has been granted	USPTO
PATENT, POST-$GRANT_{jy}$	Dummy variable equal to 1 if PATENTED =1 and YEAR > GRANT YEAR	USPTO

Table 2
Means and Standard Deviations

Variable	N	Mean	Standard Deviation	MIN	MAX
Citation-Year Characteristics					
TOTAL FORWARD $CITATIONS_{jt}$	5374	14.42	16.96	0	184
PUB FORWARD $CITATIONS_{jt}$	4911	13.03	14.48	0	150
PRIV FORWARD $CITATIONS_{jt}$	1061	2.81	4.93	0	58
US FORWARD $CITATIONS_{jt}$	3230	8.57	10.99	0	123
NON US FORWARD CITATIONS	2207	5.85	6.86	0	61
HIGH TIER JOURNAL CITATIONS	477	1.27	1.82	0	15
LOW TIER JOURNAL CITATIONS	4960	12.62	15.07	0	171
SCHOLARLY CITATIONS	6261	13.95	16.40	0	180
NON SCHOLARLY CITATIONS	176	.467	.953	0	8
PUBLICATION YEAR	5374	1998.47	.4997	1998	1999

Table 3
Means Conditional on Patent Status of Articles

	NO PATENT	PATENTED
# PUBLICATIONS	54	53
FORWARD CITATIONS	12.70	16.46
US AUTHOR	100%	100%
PUBLIC SECTOR AUTHOR	100%	100%

V. Empirical Specification

This study builds on the work of Murray and Stern (2005) by modifying their empirical framework in order to find the differential anticommons effect on public and private sector researchers along other citation divisions. As employed by Murray and Stern (2005), this study uses a fixed effects negative binomial regression to quantify the anticommons effect on the citations of articles published in *Nature Biotechnology* between 1998 and 1999. By using a fixed effects method, variables such as the author characteristics, patent back references, importance of the research discovery, the time elapsed since initial publication, and the year for which the citations were considered are all controlled for and absorbed into the fixed effects coefficients (see Appendix A for descriptions of important variables absorbed into the fixed effects). By using a differences-in-differences estimation (effectively input into the model with the Post-Grant dummy variable which equals 1 when a patent on an article is enforced), we are able to compare the citation trends of the patent paper pairs with that of the non-patented papers. The test for the impact on citation rates due to a granting of a patent from Murray and Stern (2005) is:

$$\text{Cites}_{i,t} = f(\varepsilon_{i,t}; \gamma_i + \delta_{t-\text{pubyear}} + \beta_t + \psi_{\text{POST}\_l}\text{POST-GRANT}(l)_{i,t})$$

This regression captures fixed effects for each article with γ_i, the effect of age with $\delta_{t-pubyear}$, and fixed effect for each citation year with β_t. Finally, POST-GRANT is a dummy variable equal to 1 for years when a patent is enforced.

In order to study whether the anticommons effect disproportionately affects public sector researchers, a few modifications were made to Murray and Stern's (2005) analysis. As in the analysis by Murray and Stern (2005), a negative binomial regression will be used in order to account for the over-dispersion of the citation count data. This study then divides the forward citations of the articles from Murray and Stern's (2005) study into those done by public researchers and those done by private researchers. After doing so, the same regression is carried out on both:

$$\text{Public Sector Citations}_{i,t} = f(\varepsilon_{i,t};\ \gamma_i + \delta_{t-pubyear} + \beta_t + \psi_{POST\_l}\text{POST-GRANT}(l)_{i,t})$$

$$\text{Private Sector Citations}_{i,t} = f(\varepsilon_{i,t};\ \gamma_i + \delta_{t-pubyear} + \beta_t + \psi_{POST\_l}\text{POST-GRANT}(l)_{i,t})$$

It is then possible to compare the pattern of public sector citations versus private sector citations on patent-paper pairs. Similar sets of regressions were run for High Tier Journal vs. Low Tier Journal Citations, Scholarly vs. Nonscholarly citations, and US authored vs. Non-US authored citations. The results are shown in Table 4 with the coefficient on Patent, Post Grant reported as an incident rate ratio. The coefficients should be interpreted as a multiplicative effect on citation rates. For example, a coefficient on Patent, Post Grant of 0.9 means a 10% drop in citation rate was found with the granting of a patent (anticommons effect). A coefficient of 1.0 means no effect on citation rates was found for the granting of a patent.

For all citations, there was found to be a statistically significant anticommons effect equaling -18.09% (p=0.017). In 4-2, the anticommons effect on public sector researchers was found to be -19.53% (p = 0.011), a value statistically significant at the 5% level. On the other hand, there was no anticommons effect found for private sector researchers. Instead, the citation rate was found to increase by a statistically insignificant amount of 4.18% in the post-patent period (p= 0.815) in 4-3. From this analysis, it appears that the anticommons effect is indeed a concern primarily for public sector researchers.

Further regressions were run to see if there are differential anticommons effects for categories of researchers and quality of research. A negative binomial regression for US authored citations (4-9) found that the anticommons effect for US authors was -15.96%, a result that is significant at the 10% level (p-value = .0872). In comparison, for non-US authored citations (4-10) there was found to be a statistically significant anticommons effect of -21.72% (p = .037).

As a noisy proxy for quality of research, the forward citations were categorized into two journal tiers, High for the most prestigious journals, and Low for the less prestigious journals. For citations in high tier journals, there was found to be an insignificant effect of a patent—a positive effect of 12.72% (p = .642). However, a statistically significant effect of -22.25% was found for low tier journals (p = .005) indicating that the anticommons effect is not so much a problem for high quality research.

The final analysis of scholarly vs. non-scholarly citations showed that there was a statistically significant anticommons effect equaling -17.26% (p = .027) for scholarly works as compared to an insignificant effect of 37.74% for non-scholarly citations (p = .341).

Finally, the tests of the fixed effects yielding low p-values confirm that the fixed effects are indeed an important part of explaining the citations rates and should be kept in our model. This makes intuitive sense since time-invariant article factors such as number of authors, article quality, publication quality, and age of the article should all be factors that help explain the citation rate (see Appendix A for discussion of variables absorbed in the fixed effects).

Table 4
Negative Binomial Regression—Differences-in-Differences Estimates Reported as Incident Rate Ratios

	4-1 Forward Citations	4-2 Public Citations	4-3 Private Citations	4-5 Journal Tier High Citations	4-6 Journal Tier Low Citations	4-7 Scholarly Citations	4-8 Non-Scholarly Citaitons	4-9 US Authored Citations	4-10 Non-US Authored Citations
Patent, Post Grant	**0.8191**** (.0688) pval=.017	**0.8047**** (.06917) pval=0.011	1.0418 (.1817) pval=.815	1.1272 (.2904) pval=.642	**0.7775***** (.0700) pval=.005	**0.8274**** (.0707) pval=.027	0.6226 (.2867) pval=.341	**0.8404*** (.0872) pval=.094	**0.7828**** (.09167) pval=.037
Parametric Restrictions									
Article FE = 0	#: 107 2513.86 pval=.0000	#: 107 2365.64 pval=.0000	#: 107 1022.97 pval=.0000	#: 107 356.56 pval=.0000	#: 107 2127.50 pval=.0000	#: 107 2391.87 pval=.0000	#: 107 98.65 pval=.7057	#: 107 1916.27 pval=.0000	#: 107 1468.51 pval=.0000
Age FE = 0	#: 3 56.48 pval=.0000	#: 3 54.37 pval=.0000	#: 3 13.63 pval=.0035	#: 3 5.77 pval=.1232	#: 3 48.63 pval=.0000	#: 3 52.34 pval=.0000	#: 3 6.44 pval=.0920	#: 3 38.63 pval=.0000	#: 3 29.27 pval=.0000
Year FE = 0	#: 3 17.22 Pval=.0006	#: 3 12.53 Pval=.0058	#: 3 6.28 Pval=.0986	#: 3 0.45 Pval=.9304	#: 3 13.48 Pval=.0037	#: 3 15.61 Pval=.0014	#: 3 2.86 Pval=.4129	#: 3 11.16 Pval=.0109	#: 3 10.59 Pval=.0141
Regression Statistics									
Log-likelihood	-974.04	-948.51	-557.07	-393.57	-952.06	-969.68	-205.23	-843.02	-743.89
P-value of Chi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R-Squared	0.2968	0.2954	0.3257	0.3285	0.2878	0.2935	0.4028	0.2987	0.3066
# of Citations	5437	4911	1061	477	4960	5261	176	3230	2207

* significant at the 10% level ** significant at the 5% level *** significant at the 1% level

Table 5
Anticommons Effect on Yearly Citation Rates Reported in %'s

	Anticommons Effect
Public Sector Citations	**-19.53%****
Private Sector Citations	4.18%
High Tier Journal Citations	12.72%
Low Tier Journal Citations	**-22.25%*****
US Authored Citations	**-15.96%***
Foreign Authored Citations	**-21.72%****
Scholarly Citations	**-17.26%****
Non-Scholarly Citations	-37.74%

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

VI. Conclusion

In a set of negative binomial regressions looking at the public and private sector citations on patent-paper pairs and non-patented papers, this study was able to find a significant anticommons effect of -19.53% for public sector citations. There was no evidence for an anticommons effect on private sector citations. In comparison with Murray and Stern's (2005) results which found that the overall anticommons effect on all researchers is 9-17%, this study is evidence that the anticommons effect is primarily relevant for public sector research. This is in align with the initial hypothesis that public sector researchers may be more easily deterred from a research area requiring multiple licensing of patents than private sector researchers since their financial resources on average are much less than those of private sector researchers. Perhaps patent thickets are present primarily in "hot" areas of research that promise to bear patentable products with broad usage appeal, which provides enough incentive for private sector researchers to overcome the initial anticommons effect of the patent thicket. Public sector researchers on the other hand are generally not as incentivized by the potential for generating profit from patentable products and thus prone to a salient anticommons effect.

It appears on initial analysis that patent thickets do not have an effect on high quality follow-on research, at least based on the prestige of the journal itself. It does however, have a very significant effect on research published in low tiered journals (-22.25%). This makes intuitive sense since research deemed "high quality" is likely to be funded generously compared to lower quality research which would have a harder time securing grants. A lack of funding would discourage researchers from negotiating patent rights and conducting research in an area with dense patent thickets.

The regression on scholarly and nonscholarly citations is also unsurprising. It is expected that the anticommons effect should be a problem for those actually conducting research and using the patented content of the patent paper pair. Unfortunately, we are unable to tell if the anticommons effect affects nonscholarly works because of the small number of citations belonging to this classification.

Finally, a regression on citations from US researchers provides evidence (at the 10% significance level) that there is an anticommons effect of -17.38%. An even greater and statistically significant result for non-US research citations was found (-21.72%). Further research needs to be done to determine why this would be the case. Perhaps foreign researchers face greater obstacles in obtaining licenses for patents or they are less able to afford them compared to their American counterparts.

Limitations

There are several important limitations to consider for this study. Firstly, the degree of the anticommons effect is greatly dependent upon the number of patents that "overlap" in a particular research topic (the greater the number of patents in a given research area, the more this "patent-thicket" will prevent follow-on research from occurring). This is controlled for in this study using the article fixed effects variable. However, because the fixed effects absorbs the number of patent backward citations among many other factors, it is not possible to look at the degree of how the denseness of the patent thicket for an article affects subsequent citation rates.

Secondly, this study only looks at articles published in a limited time frame (1998 and 1999) in only one journal, *Nature Biotechnology*. For this reason, the results of this analysis may not be generalizable to other areas of research besides biotechnology, or to other time periods. In addition, it is not possible to follow an overall trend in the impact of the anticommons effect (i.e. Is the anticommons effect a phenomenon that is becoming increasingly important over time? Or is the anticommons effect diminishing with time?).

This study only looks at articles published in a limited time frame (1998 and 1999) and looks at only a population of the forward citations between the years 2000 and 2002. Because only the first few years of the post-patent period is analyzed, it is conceivable that the anticommons effect on a given article decreases with time. For example, perhaps the anticommons effect is only apparent in the first 3 or 4 years and after that, the citation rates become comparable to non-patented papers. By following the citation trends in this sample of articles for a longer period, it would be possible to determine such a trend. In an ideal study, the articles would be tracked to a post-expiration of the patent in order to see if there is a jump in citation rates on an expired patent-paper pair, which would also indicate the presence of the anticommons barrier to research.

Policy Implications

This new evidence that public sector researchers face the brunt of the anticommons effect caused by patent thickets may warrant a move by the policymakers to alleviate some of the burden they face. As discussed earlier, a recent high profile issue surrounding the enforcement of patents on upstream human embryonic stem cells forced a move by the National Institutes of Health to negotiate lowered prices for access to the cells for academic and government-funded researchers. Perhaps this policy of negotiating lower prices for patent licenses for public sector researchers should be universally adopted in order to counteract some of the anticommons effect. Because public sector research is also more likely to pursue projects that benefit causes without an apparent profitable outcome, it is in the interest of society and the government to support public sector research and mitigate the unduly obstacles it faces. It is however, reassuring to find that at least in this narrow analysis, there is no sign that there is a dampening effect on high quality research as proxied by citations in high tiered journals.

With the development of the anticommons theory from its beginnings as a historical account to its theoretical underpinnings and most recently to grounding in economic modeling and empirical proof, this study directs the vein of progress to findings that have important implications in the policy arena. Further research and understanding of the causes and effects of the anticommons as it relates to scientific research will allow policymakers to better assess the US patent system and be able to devise a more optimal incentive structure to encourage investment in upstream research without sacrificing downstream development.

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Appendix A – Variables Absorbed by Fixed Effects

The following variables are controlled for in our analysis by including article, age, and publication fixed effects in the regressions which absorb any confounding variables present across article characteristics, the effect of the age of the article, and publication qualities.

Patentability

It is reasonable to expect that a paper that is more patentable than another will have more citations than the other, just by virtue of its content being deemed worthy of a patent (the three requirements for patentability are novelty, usefulness, and inventiveness). Non-patented papers that are indeed less patentable may thus be less novel, useful, or inventive than their patent-paper counterparts.

Number of U.S. authors

The number of U.S. authors of a research paper may contribute to the likelihood of being granted a patent since international authors may face a greater barrier to applying for a patent due to geographic concerns and familiarity with the USPTO system.

Author Age and Rank

It may be expected that the older the author and the higher the rank of the author (as determined by the number and impact of his publications), the more likely their work will be cited.

Backward Citations

Backward citations of an article can give a general idea of how much prior work has been done in a given area of research. It may be that the less prior work that an article is founded upon, the more nascent the area of research and thus the more likely follow-on researchers will have to cite the given article in order to build on this particular research area.