Why do technology firms publish scientific papers?

The strategic use of science by small and midsize enterprises in nanotechnology

Yin Li [a,*]

Jan Youtie [b]

Philip Shapira [c,a]

Affiliations:

a. School of Public Policy, Georgia Institute of Technology, Atlanta, GA 30332-0345, USA
b. Enterprise Innovation Institute, Georgia Institute of Technology, Atlanta, GA 30308, USA
c. Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, Manchester, M13 9PL, UK

Corresponding author:

* Yin Li; Email: yli1508@gatech.edu;

Pre-Print – December 27, 2014

Revised version published in the *Journal of Technology Transfer* (Online First - January 12, 2015). The final publication is available at http://link.springer.com/article/10.1007/s10961-014-9391-6

Abstract

In the emerging technology domain of nanotechnology, a significant portion of small and midsize enterprises have contributed to the scientific literature by publishing their research and development results. However, while considerable attention has been paid to patenting by small and midsize technology firms, the underlying business motivations for such firms to publish scientific papers are not well understood. This paper investigates the scientific publishing patterns of smaller firms engaged in nanotechnology and the factors that underlie this phenomenon. Based on an analysis of 85 US small and midsize enterprises with a minimum of four nanotechnology patents or publications, we test three hypotheses about corporate publishing: reputational gains, absorptive capacity, and strategic spillovers. We find that the small and midsize firms in our sample are more likely to publish when their work is associated with public science and when it involves a greater technological focus, but having a university collaborator is not a significant factor. The results from this study of nanotechnology enterprises suggest that small and midsize technology firms selectively manage and disclose their research based on internal developmental and capacity drivers.

Key Words

Small firm innovation; intellectual property strategy; corporate publication; patenting strategy; emerging technology

JEL Classification Codes

C5; L2; O31; O32; 034

1. Introduction

Business firms have not traditionally been considered as major contributors to publications in the scientific literature, with the exception of some large corporations (usually in science-based industries) that publish significant amounts of R&D (Hicks 1995). However, recent studies of emerging technology fields (Youtie et al. 2008, Shapira et al. 2011) show that corporate publishing in peer-reviewed scientific journals is not only more prevalent than might be expected but also involves a significant number of small and medium-sized enterprises (SMEs). In the nanotechnology domain, 8% of publications (or more than 54,000 publications) from 1990 to 2009 have a corporate author involving over 17,000 unique corporate entities, including a large number of small firms (Youtie and Kay 2014).

The motivations for smaller technology firms to publish are not obvious. From both business strategy and economic points of view, it may seem counterintuitive for firms to publish because publishing limits a firm's ability to appropriate the value of the underlying work through intellectual property protections such as patenting. So why do firms even seek to publish in scholarly literature? Given that SMEs usually find it difficult or costly to protect their patent portfolio, a potential motivation for publishing might be to gain associated positive benefits. Such benefits could include enhanced reputation (Allen 1983, Hicks 1995), retaining important scientists (Cockburn and Henderson 1998), or strategic manipulation of the process of knowledge diffusion through scholarly publishing (De Fraja 1993, Harhoff et al. 2003). Yet, even if publishing might yield benefits, how are the amount of publications and the timing of the publishing determined within the firm? Following Merton (1957) and subsequent work on priority setting in science, particularly the business performance of science (see, for example, Stephan and Levin 1996, Murray 2002, Liu and Stuart 2014), we would expect to find a complex set of relationships involving recognition and reward structures, managerial strategies, and organizational context and linkages to underlie the manifestation of published corporate-authored research papers. Unlike scientists in universities and research institutes, most corporate researchers do not have complete autonomy to pursue recognition and rewards in the scientific community. While acknowledging that some individual researchers may undertake "bootleg" projects without prior approval (Criscuolo et al, 2014), management structures within business typically exercise a degree of control over open scientific publication by corporate researchers for intellectual property concerns as well as competitive strategy reasons. Thus, the number of publications by a firm is not solely determined by the research productivity of scientists in the firm. From a management perspective, a firm would have to make the choices between whether to disclose its R&D (or maintain it as trade secret), how to disclose (i.e. publishing or patenting), and when to disclose, in order to maximize the strategic benefits from its R&D results. In this sense, to answer the question of why small technology firms publish, we pay less attention to research productivity issues within the firm, but rather focus on the strategic motivations of why some small companies publish their R&D while the majority of other companies do not.

Much of existing work on firm publishing examines large corporate publishing patterns and the factors that underlie this phenomenon, primarily in biomedical domains. The particular contribution of this paper is to focus on strategically interesting and relatively unexplored publishing behaviors by an important subset of high technology SMEs. Our focus on nanotechnology is useful as it highlight SME firm publishing activity in an emerging science domain which is multidisciplinary and which has near term commercialization potential (Youtie et al. 2008). The study considers several drivers of SME publishing and tests hypotheses related to reputational gains, internal R&D capacity development, and strategic spillovers in early stages of technology development. The next section discusses the literature and concepts which motivate our hypotheses. This is followed by an explanation of the data set of firms used for the empirical analysis and the presentation of our model and its results. We conclude with a discussion of the findings and their implications and limitations.

2. Literature Review

It has been observed that, in many science-based industries such as chemistry, electronics, and biotechnology, business firms sometimes allow their corporate scientists to publish company-funded research through peer-reviewed journals, academic conferences and other venues of open science (Hicks 1995, Cockburn and Henderson 1998, Lim 2009). Publishing in scientific literature is usually not financially rewarding for private companies, but publishing might result in unexpected impacts on the value of the underlying innovations. In his seminal article about the economics of innovation, Arrow (1962) considered the characteristics of knowledge as a public good that is not depleted when shared but which could reduce private incentives to invest in knowledge production. In this light, publishing by firms seems to be in contradiction to economic principles: instead of holding information private to maximize its value, the publishing firm voluntarily reveals private knowledge in the public domain.

Practically, there are several reasons why technology-oriented firms might refrain from publishing. The most central one is that publishing can severely jeopardize a firm's ability to appropriate intellectual property rights that might be associated with inventions. In particular, early publishing can destroy the opportunity to patent (Rubin 2011). Scientific publications, like many other forms of disclosure, including dissertations, scientific posters, grant applications, and symposium speeches, may create prior art, which could precludes patentability of the disclosed innovations in many parts of the world, including in Europe. In the United States, the patent system allows inventors to file for a patent within a grace period of one year after their own public disclosure (but then rights to patent could be lost in Europe and in many other countries). Even in the US, publication could still put inventors at a disadvantage, since competitors could potentially use the disclosed knowledge to develop alternative yet functionally similar patents. Publishing also has costs, including opportunity costs, as it takes time and diverts resources from other strategic business activities, such as further applied research, product development, and internal process innovation. Research on scientific productivity has found that publishing and patenting tend to be substitutes since researchers to allocate their limited time and energy (Campbell et al. 2002, Thursby and Thursby 2002). Others have pointed out that encouraging publishing might cause agency problems for corporate scientists, since publishing could be more rewarding for individual scientists than focusing on R&D activities for the corporation (Smeth and Raffo 2013).

Nevertheless, it has been established that large firms do publish in scientific journals on a regular basis. Large corporations publish hundreds of papers yearly, and “firms such as Philips, Hitachi, ICI, Ciba, Siemens, Sandoz, Roche, Hoechst and Toshiba contribute as much to the public literature as medium sized universities” (Hicks 1995, p. 403). The disciplines where firms make substantial contributions in terms of generating highly cited papers include molecular biology, chemistry, life science and physical science (Hicks 1995, Cockburn and Henderson 1998). Scholars have suggested multiple potential motivations for firms to publish. Firms might want to openly disclose part of their knowledge in order to induce other firms to reciprocate (von Hipple 1987, Eaton and Eswaran 2001), to keep bright researchers working for them and stimulate R&D productivity (Cockburn and Henderson 1998), or to enhance their reputations in academic and industrial communities (Allen 1983, Hicks 1995). Additionally, publishing firms may seek to trigger network effects or pecuniary spillover (Harhoff et al. 2003), to shorten patent races (De Fraja 1993), or as a defensive strategy to maintain access to knowledge when costs of intellectual property protection might be too high (Adams and Henson-Apollonio 2002).

Several reasons are put forward as to why corporate publications are most likely to be produced by large firms. Research papers are often the result of longer term research, which is more likely to be conducted at established corporate labs (Hicks 1995). Large corporations have both the resources and incentives to undertake longer-term research and technological knowledge development (Pavitt 1989). Such incentives might come from the market power, which makes large corporations believe that they have the ability to appropriate uncertain results from basic research (Nelson 1962). Since smaller firms typically have neither sufficient resources nor market power, this logic would suggest that it would be unusual for small firms to conduct longer-term research and to publish from it, even though certain SMEs may benefit from other innovation advantages including flexibility, ease of communication, and dedication to bringing new products and services to markets (Acs and Audretsch 1990, Verhees and Meulenberg 2004). Yet, there is some prior work which highlights not simply the role of small firms in pioneering research-driven innovations but also the engagement of such firms in early publishing and communication, for example in the development of instrumentation (Lenoir and Lécuyer 1995, Mody 2006). Moreover, in our own analyses, we find that publishing in scientific journals is not exceptional, but is rather a frequent practice among nanotechnology firms of many sizes. Shapira et al. (2011), found that in the earliest discovery stages of nanotechnology (1991-2002), the corporate sector published more nanotechnology papers than patents (although this relationship changes, with patents becoming relatively more important in subsequent moves towards exploitation). Small- and medium-sized nanotechnology companies are represented among the companies that publish.

What factors might explain publications from SMEs in science-based domains such as nanotechnology? Small companies usually lack the scale and internal resources to sustain basic research, and even when they do, they would not have the broad product portfolio to exploit uncertain results from such research. For small companies conducting basic research, a conventional strategy would be to appropriate the benefits from intellectual property rights, such as patenting and licensing. Therefore, the publication strategies of nanotechnology SMEs need to be examined relative to their specific internal motivation and external drivers. Literature suggests that such drivers for companies to publish might include: *reputational gains*, *internal R&D capacity development*, and *strategic spillover in early stage of technology development*. Below, we consider each of these drivers and associated hypotheses.

Reputational gains. One of the key benefits from disclosing knowledge publicly is reputational gains (Allen 1983, Hicks 1995, Muller and Penin 2006). Reputational gains for firms or firm managers might offset part of the losses in profits (Allen 1983, p.17), but more importantly, reputational gains from publications give credibility to the innovating firm in its field of research (Hicks 1995). Publications show what the firm is doing and how good it is. Such credibility could be the pathway to a broader information network in the academic and industrial community. Publications can signal the firm's competence to potential partners that it is a worthy collaborator, i.e. in order to solve adverse selection problems (Muller and Penin 2006). At the same time, publications may allude to non-published, tacit knowledge within the firm that could be potentially exchanged with other innovators (Hicks 1995). In both cases, publications enable links, in particular links to external scientific and technical information and advice and to further resources which (amongst other things) may increase the likelihood of successful innovation.

The importance for industrial innovation of external sources of innovation such as universities and industrial partnerships has long been recognized (Rosenberg and Nelson 1994; Freeman 1991). In recent years, it has been suggested that the US innovation system has evolved to encompass more open forms of innovation combining internal and external resources, reduced inter-organizational barriers to knowledge transfer, and networked sharing of risks and rewards (Chesbrough 2003). Nanotechnology, as a domain of research and innovation that has emerged over the past two decades, can be expected to incorporate both well-established and novel patterns of innovation collaboration (Mowery 2011). The characteristics of today's innovation system and the interdisciplinary nature of nanotechnology require external links for innovation success for reasons which include accessing specialized knowledge. Among other things, reputation is an important factor in establishing links. For small companies, publications could be a relatively inexpensive way to gain reputation and access external resources for innovation. For example, Wang and Shapira (2012) find that co-publishing between US startup nanotechnology firms and university researchers who are highly productive generators of research articles is associated with technological potential, as measured by receipt of Small Business Innovation Research (SBIR) awards.

University researchers also have economic if not societal motivations to work with the private sector. Some academics get monetary rewards from working with industry ranging from consulting payments and stipends to corporate stock and other forms of compensation (Stephan and Everhart 1988). In other cases, the scientist's reputation is enhanced by the public utility from having research findings being incorporated into a commercial offering. Other factors have created a favorable climate for university-industry collaborations, at least from an intellectual property standpoint, including the ability of companies to pre-screen scholarly articles before they go to press, the declining cycle time between research and commercialization, and the search by scientists for diversified sponsorship support beyond the federal R&D budget (Stephan and Levin 1996). Based on these perspectives, we hypothesize:

H1: Nanotechnology SMEs are more likely to publish in science journals when they intend to include external researchers in R&D activities.

Internal R&D capacity development. In contrast to the view of publications as a means of signaling to the environment, an alternative argument is that firms are encouraged to publish to develop internal capacity for research and to raise R&D productivity. The impacts of a "pro-publishing" strategy on internal R&D productivity may be both direct and indirect. The direct effect includes helping firms to hire bright researchers, rewarding them on the basis of their standing in the publication ranking hierarchy, and allowing the firm to monitor and reward researchers in a cost effective manner (Cockburn and Henderson 1998, p.162). Particularly for small firms, it is relatively inexpensive to allow scientists to publish compared to other forms of compensatory incentives. The indirect effect is associated with internal capacities developed from absorbing and coalescing basic research results into publications. Investment in basic research, while being unable to produce appropriable knowledge immediately, can help the firm to create capacities to recognize, assimilate and exploit knowledge created elsewhere (Cohen & Levinthal 1989, Gambardella 1992, Koza & Lewin 1998). Such absorptive capacity might help researchers in the firm to better understand how and where to conduct research of a more applied nature, or might be essential for evaluating the outcomes and implications of applied research (Rosenberg 1990). Since nanotechnology is a science-based field, the ability to absorb and transform scientific discoveries is important for industrial innovation and exploitation. Research in basic science and its subsequent publications may help the firm to search for, learn from, and assimilate the latest discoveries in public science—where public science refers to research that appears in published articles and is subsequently included as a non-patent reference. Hence we hypothesize:

H2: Nanotechnology SMEs are more likely to publish when their source of knowledge is public science.

Strategic spillover. Publication, among other forms of open disclosure of innovation, could be a strategic behavior of profit-seeking firms. In one of the initial studies of innovation-sharing by firms, Allen (1983) describes a phenomenon he calls "collective invention" in which innovators in the 19th century English iron industry publicly revealed their higher efficiency furnace designs. Allen suggests that such behavior might actually increase firm profits, because the revealed innovation is to some degree specific to assets owned by the innovator. Studies of industrial organization have found similar patterns of corporate innovation revealing in many modern industries, such as semiconductors (Harhoff 1996, Lim 2009), medical devices (von Hippel and Finkelstein 1979), and information systems (Morrison et al. 2000). A profit maximizing logic in these cases, argued by industrial organization economists, is that revealing innovation through disclosure increases diffusion of that innovation relative to patenting, licensing or being held as trade secrets. Firms can benefit from such increased diffusion. One particular form of benefit is that innovations that are freely revealed and adopted by others can become formal or informal industry standards (Harhoff et al. 2003). Such a strategy has the potential to give monopoly power to the innovator if it preempts the development or commercialization of other versions of innovation. Or it might create competitive advantages for the innovator, if the innovation is to some degree specific to the unique assets owned by the innovator (Teece 1986).

Publications, as a form of a freely revealed innovation, could also represent a similar strategy to increase the influence of the innovator. We might call such behavior "strategic spillover" as it increases spillovers for strategic purposes and benefits. Strategic spillovers could be a particularly relevant motivation to high-tech SMEs that lack the resources to promote formal standards setting. It might also be relevant in the context of an emerging technology where room for improvement is abundant and standards of products and process are yet to be defined. Hence we hypothesize:

H3. Nanotechnology SMEs are motivated by the benefits of strategic spillover to publish in the early stage of technology development.

The next part of the paper presents the data and methods, variables, and model used to test the three hypotheses raised in this section.

3. Data and Methods

3.1 Data

The empirical analysis of this paper is based on a data set of corporate R&D activities by firms engaged in nanotechnology. It should be noted that nanotechnology can be delineated as the analysis and manipulation of materials and structures at very small scales (1-100 nanometers) where novel properties are evident (PCAST 2005). Applications for nanotechnology are evident (or anticipated) in a wide range of industries, including construction, cosmetics, food packaging, electronics, energy and environment, healthcare, materials, and transportation. Nanotechnology has been seen as an emerging domain of general use technology that has attracted substantial public and private interest in research and development (Youtie et al. 2008; Shapira and Wang 2010). Nanotechnology R&D activities including research publication and patenting started to grow broadly in the early 1990s, and have since continued to expand (see for example, Youtie et al. 2008). As part of the Center for Nanotechnology in Society (CNS-ASU 2014), Georgia Tech's Program in Science, Technology and Innovation Policy (STIP 2014) has tracked the body of nanotechnology publications and patents, using a definition of nanotechnology based on a multi-stage Boolean search strategy (Porter et al. 2008, Arora et al. 2013). One of the products of STIP's efforts to track nanotechnology development is a global panel data set of nanotechnology publications and patents generated by corporate entities, or simply referred as "Nanotechnology Corporate Panel" (Shapira et al. 2011). Corporate nanotechnology publications and patents are observed to exhibit a two-stage growth trend. As noted earlier, in the initial period (1990–2003), corporations produced more nanotechnology publications than patent applications. However, after 2003, corporations filed about an average of 1.3 patent applications per patents (Shapira et al. 2011, p.6). Lux Research (2007) suggests that in the discovery stage, corporations focused on nanotechnology research and new knowledge development; while in the innovation stage, emphasis is placed on products, venture capital and equity finance. Yet, it is not fully clear what factors generate the trend of corporate publications in the nanotechnology domain, particularly as corporations continue to publish even as they ramp-up patenting activities. In this paper, we are particularly interested in what drives publishing among smaller nanotechnology enterprises.

The STIP Nanotechnology Corporate Panel contains a total of about 6,000 US corporations (large firms and SMEs) with at least one nanotechnology publication or patent. The starting point for this study's analysis is a random sample of 125 US-based SMEs with four or more nanotechnology publications or patents that were in business (as of summer 2012). In this study, we began by defining SMEs as enterprises that were not included in the Fortune 1000 list of the largest American companies. Checks of the number of employees of these firms with employment data in Dun & Bradstreet and Reference USA indicated that all of them had fewer than 500 employees (which is generally the threshold for defining a small or mid-size business in the US). We set a four publication/patent threshold to avoid including firms with only one nanotechnology patent or publication, which would represent more of an incidental than a specialized connection to nanotechnology. Our focus was on SMEs that were in business and not part of another corporate enterprise, thus having the ability to control their strategic orientation. The SMEs were also selected to be representative of the broader size and industry mix of these types of firms. Drawing the set of 125 US-based small and medium-sized enterprises required selecting 193 firms using a random-sampling with replacement design, because 68 of the initially selected firms were found to be either acquired by or subsidiaries of large corporations or out of business (Youtie and Kay 2014, Kay et al. 2014).

Comparing publishing and patenting patterns of these 125 SME panel members to the publication/patenting mix a sample of 125 large US firms in the corporate panel, we found that the majority of large corporations, or 97 out of 125 companies, had both publications and patent applications, demonstrating their interests in conducting and exploiting research in nanotechnology (Table 1). Only a small fraction of large corporations (10 out of 125) had not published. For SMEs, the strategy of publication and patenting was more polarized. There were 40 SMEs that both published and patented, 45 with patents but no publications, and 40 with publications but without patents. While these sample estimates are not conclusive, they show the significant prevalence of publishing by SMEs active in nanotechnology, with 80 of 125 (or 64%) producing papers in scientific journals.

[INSERT TABLE 1 ABOUT HERE]

The 40 smaller companies without patent records were then excluded from subsequent analysis, mainly because publishing without patenting suggests that it is premature for commercial exploitation or that the firm is focused primarily on research. Since our interest is on understanding the strategic publishing behaviors of SMEs that are also active in exploitation (as measured by patenting), these 40 companies would have no variation relative to the variable of interest. For the remaining 85 companies, detailed publication and patenting characteristics were obtained respectively from the Web of Science and the Derwent Innovation Index, both published by Thomson Reuters. The 85 companies in our sample generated a total of 2999 patent documents from 1990 to 2012. Among them, 40 companies had at least one publication ("publishing firms"). The publishing firms published 1050 journal articles and filed for 1932 patents, while the non-publishing (but patenting) firms filed for 1067 patents. Concerning the number of firms in our dataset, it is time consuming to organize this data, particularly to connect it accurately with other databases. We sought a group of sufficient size with less heterogeneity than if we were to include the total population of all firms with a nanotechnology publication or patent. The firms in this study still account for a non-insignificant share of the total number of nanotechnology patent documents or publications with a private-sector inventor/assignee or private-sector-affiliated author respectively. Compared with the total database of US nanotechnology SMEs, the companies in our sample account for 27% of the private-sector-related patent documents and 21% of the private-sector-related publications. We note that the use of a small but targeted purposive sample has been applied in other studies. For example, Almeida and Kohut (1997) use a purposive sample of 57 semiconductor firms to focus on highly-cited design patents filed by enterprises.

We pool the panel data into three periods: 1990 – 2000, 2001 – 2005, and 2006 – 2012. The three periods demarcated based on two major events in the history of US nanotechnology development. In 2001, the US federal government launched the National Nanotechnology Initiative (NNI) program to coordinate agency efforts in providing funding for nanotechnology research and development. In 2006, the federal government substantially strengthened centers for nanotechnology research around the country with this being an initial peak year for US federal investment in Nanoscale Science and Engineering Centers (NSECs) and Materials Research Science and Engineering Centers (MRSECs) by the National Science Foundation as well as Nanomedicine Development Centers and Centers of Cancer Nanotechnology Excellence by the National Institutes of Health. Rogers et al. (2012) find that many firms developed relationships with the NSECs to observe research activities and have access to student graduates. Statistically, our publication and patent sample is about equally distributed across the three periods. The justification for pooling the panel data into these three periods rather than analyzing data at the level of the calendar year is because neither publishing nor patenting occurs yearly for most small companies, thus a firm-year panel would be unbalanced. Because of these concerns, our unit of analysis is the firm-period which gives us 146 total observations.

3.2 Variables

Based on the three hypotheses in the preceding section, we propose that the firm's decision to publish in scientific journals is related to relationships with external researchers (*H1*), reliance on public science (*H2*), and early technology development (*H3*). The dependent variable of interest is the strategy to publish in peer-reviewed journals by the focal firm in the focal period of time. It involves two levels of decisions: whether the firm decides to publish, and how many publications it decides to publish.

Relationships with external researchers (*H1*) are measured by the proportion of patents with external coassignees in the focal time period. We distinguish two types of external coassignees: universities and other companies. Research collaborations between universities and companies have quite different motivations and operational modes than those between two or more companies alone. Collaboration with universities often involves generating generic knowledge (or "basic research"), while collaboration between companies tends to be more specific and to focus on problem solving. University researchers have a stronger orientation to publishing than industrial researchers do. These differences suggest that the likelihood of publishing would increase when the collaborator is from a university than when the collaborator is from industry. We acknowledge that individuals at companies and universities may work together without co-patenting (for example, they may work on joint research projects) and further recognize that the presence of a university-industry coassignee relationship depends on the form of agreement that these two organizations negotiate. With these limitations noted, we construct the *UNIV* variable by counting the proportion of patents with university coassignees in each period. Similarly, variable *INDUS* is the proportion of patents with industry coassignees. *UNIV* and *INDUS* are both expected to be positively associated with the number of publications, but *UNIV* is expected have a larger marginal effect than *INDUS*. Publishing firms in the dataset have an average of 4% of patents with university coassignees (*UNIV*=4%) and an average of 8%

of industrial coassignees (*INDUS*=8%). In comparison, non-publishing firms average 8% and 14% of patents with university and industrial coassignees, respectively.

Reliance on public science (*H2*) is measured by the average percentage of non-patent literature (*NPL*) citations in the focal company's patents. *NPL* represents citations of a patent to non-patent sources, such as journal articles and books, in a patent. Previous research has established that *NPL* is an indicator of underlying information flow from basic science to industrial technology development, but such information flow might be highly mediated (McMillan et al. 2000, Meyer 2000). In this regard, *NPL* is a proxy of a firm's absorptive capacity in directing knowledge flow from published scientific articles to its own innovation process. Note that while the external link hypothesis hints at information exchange with external researchers, it emphasizes the external, relational aspects. This hypothesis concerning *NPL* citations focuses on the internal aspects. In other words, firms learn from published scientific articles and cite this literature in patents, but they do not necessarily have to establish inter-personal relationships with the researchers performing the research published in the articles. We expect that the *PNPL* variable (proportion of *NPL* citations) is also positively associated with the number of publications. In the dataset, the average *PNPL* for publishing firms is 18%, and the average *PNPL* for non-publishing firms is 14%.

We measure early technology development by counting the average number of technology factors covered by the company's patents. A technology factor is constructed using Kay et al. (2014) – in this work, there are 35 categories of patent classifications based on citing-to-cited International Patent Classification (IPC) categories for 7 years of European Patent Office (EPO) data to represent technological distance. This definition of technology factors has the advantage of classifying patents by the current, global citation distance instead of the IPC's hierarchical administrative structure (i.e. IPC classes). Kay and colleagues indeed found that 30 of the 35 factors that emerged from the citing-to-cited category analysis crossed conventional administration groupings (i.e., sections). Since innovation in a new area of inquiry often involves novel combinations of knowledge from difference sources, we assume that patents generated in new technology development would cover a larger number of technology factors. We use a thesaurus in the bibliometric software Vantage Point to map the 2999 patents' IPC class codes to the technology factors. The three categories of technology factors with the largest number of patents in our data set are semiconductors, photolithography, and chemistry & polymers. We then construct a technology factors (*TF*) variable by counting the average number of technology factors per patent. *TF* is about 6.3 on average for publishing firms and 7.6 for non-publishing firms. It is expected that *TF* is positively correlated with the number of publications. Table 2 summarizes the comparison of independent variables by publishing and non-publishing firms.

[INSERT TABLE 2 ABOUT HERE]

We include average number of inventors per patent (*INVENTORS*) to control for R&D outlay, the number of patent applications (*PATENT*) to control for research productivity, and a control for time trends (*PERIOD*). Larger R&D outlays and higher research productivity are expected to contribute to a higher likelihood to publish and a larger number of publications. However, we have not used conventional measures such as R&D expenditure, because there is not a source with sufficient coverage for tracking the R&D expenditures of these small firms over time. Instead, we take advantage of our rich patent data to construct consistent, time-variant control variables. The number of inventors is a proxy of the size of the research project as well as R&D labor inputs. The number of patent applications represents realized R&D efforts. We also control for the time trend by using a number sequence to represent the three time periods (Table 3).

[INSERT TABLE 3 ABOUT HERE]

3.3 Model

We model nanotechnology SMEs' publishing in scientific journals as a function of the number of collaborative relations with external university or industry researchers, the usage of public science in patented innovation, and the number of technology factors covered by patents.

$$PUB_I = f\,(UNIV_i,\ INDUS_i,\ PNPL_i,\ TF_i)$$

While we are interested in corporate publications in scientific journals, we have to consider the meaning of publishing in an industrial setting as opposed to academic institutions and the varying research productivity among companies. For these considerations, we estimate two models with different choices of dependent variable specifications. First, we estimate a binary model concerning whether or not the company has published (*PUBDUMMY*). This specification assumes that whether the company has successfully attempted to publish is of primary importance for its innovation strategy, while the realized number of publications is secondary. Put it in another way, the main difference is between publishing and non-publishing firms, rather than on how much publishing has occurred. Second, we specify the dependent variable as the discrete number of publications (*PUBCOUNT*), by assuming that the number of publications makes a difference in a firm's innovation strategy. Since the number of publications could also reflect "realized research productivity" counts, this specification can be ambiguous, unless one introduces control variables to account for the effect of scientific productivity. Accordingly, we estimate Logit and Negative Binomial regression models.

It is worth noting that we use normal Negative Binomial regression model instead of Poisson model or Zero-inflated Negative Binomial model. We choose a Negative Binomial regression model over a Poisson model to account for the presence of over-dispersion in the data. Although an excess of zeroes in data might suggest a zero-inflated model, we use a normal Negative Binomial model in part because the Vuong test for a zero inflated negative binomial vs. standard negative binomial indicates a z-test that is not significant. Also from a theoretical standpoint drawing on Simeth et al. (2013), we believe that the assumption of different data generation processes for each subset of the zeroes (i.e. incidental and structural zeroes) could not hold in this context. In this research, structural zeroes refer to companies that do not generate any publications, while incidental zeroes refer to companies that are expected to publish but do not. Since all companies in our data had at least one patent, they are all R&D conducting companies with publishable innovations. The firm's strategic decision is between filing a patent, publishing a paper, or both. Under this belief, we are confident that all the structural zeroes have already been eliminated. Therefore, a more appropriate model is the normal Negative Binomial regression.

3.4 Regression results

Regression results from the two estimation procedures are presented in Table 4. A series of findings are detected. First, we find that the proportion of citations to scientific journals in patents (*PNPL*) – a measure of reliance on public science – is associated with a higher likelihood and also a larger number of publications. As shown in the binary model (1), a 1% increase in non-patent literature (*NPL*) citations is associated with a higher likelihood of publishing by 0.9%

at mean values. Similar results are observed in the discrete model of publication counts (2). Since we have included research productivity (i.e., number of patent applications) and research intensity (i.e., number of papers) in the model as control variables, the results are more robust with respect to concerns about the effect of research productivity on publishing behaviors. We find that firms use publishing for strategic purposes in developing internal capacity for the use of public science, regardless of their level of research productivity. For nanotechnology SMEs, this finding confirms that public science is of importance as a source of knowledge for these nanotechnology SMEs. When nanotechnology companies use more public science in their innovation (as indicated by non-patent references), they are also more likely to publish and contribute to science.

[INSERT TABLE 4 ABOUT HERE]

Second, we find weak associations between firm publishing and relations with external actors. In both models, *INDUS* is not statistically significant. In another words, having collaborators in other companies does not seem to have an influence either on the firm's decision to publish or the amount of publications it chooses to produce. With respect to the binary model, the *UNIV* variable is not significant, either. However, we do find that a higher percentage of patents with university coassignees are associated with a larger amount of publications in the discrete model, even though the significance level is at $p<.10$. It might be interpreted that collaboration with university researchers can induce companies to publish more papers, but whether the firm would attempt to publish at all is not significantly influenced by its external relationship with university or industry collaborators.

Third, *TF* is found to be insignificant in the binary model, but associated with a lower number of publications in discrete mode. We have interchanged *TFs* with IPC classes and received similar results, suggesting that the results are robust across different patent classification approaches. Contrary to our hypothesis, firms publish fewer articles when their innovations cover more technology factors, or in another words, innovations with higher uncertainties. In addition, technology factors covered by a patented innovation do not have a significant impact on firm decision to publish. This logic led to the expectation that nanotechnology SMEs might be interested in publishing when engaging in areas of innovation with higher uncertainty. Instead, the results show that these firms publish more when their innovations are in areas covering fewer technology factors. These results contradict the findings of Almeida and Kogut (1997), whose study of semiconductor design patents observes that small firms were more apt to focus on specialized patent areas which covered more technological areas than their large firm counterparts. One interpretation of this result is that nanotechnology SMEs are not significantly considering spillover strategies when innovating in novel areas of development. Instead, they tend to patent on those occasions. Signaling theory as referenced in our rationale for *H1* can partly explain why these firms publish when working in areas covering fewer technology factors. Areas that cover fewer technology factors may represent more established topics of inquiry, in which case, contributions to these established topics might be easier to recognize by the scientific community and become a preferred option for signaling underlying capabilities.

In terms of control variables, we find that research productivity measured by the number of patents is significantly associated with the likelihood to publish and positively related to the amount of publications. There is no significant time trend in either the likelihood to publish or the amount of publications. In the earlier part of the paper, we observed that both corporate nanotechnology publications and patents grow over time, but the growth rate of patents increases faster than that of publications. While our regression results do not show clear time trends, this could be partially explained by the decrease in the usage of science literature in patents. In our sample, the average percentage of *NPL* in patents decreased from 22.3% in the pre-2000 period, to 16.8% in 2001-2005, and to 11.2% in 2006-2012. One explanation might be related to nanotechnology's transition from discovery to application (Shapira et al. 2011). Industrial R&D towards applicable development usually does not require state-of-the-art science, but it does require a large amount of industrial know-how which may be reflected in the higher likelihood to patenting in the later period.

4. Conclusions and discussion

In this paper, we explored the phenomenon of small- and medium-sized technology companies' publishing their research results in scientific journals. We examined the publishing and patenting records of a sample of US companies in the nanotechnology domain to establish that firms participating in this emerging area do publish, regardless of the size of the company. We then tested three hypotheses as to why companies publish using a panel dataset of nanotechnology SMEs' publishing and patenting records. The analysis is performed using publicly available bibliometric publication and patent data, which has the advantages of open access and easily replication by other researchers. However, the approach is limited to some extent because this method does not allow us to identify and represent small firms involved in nanotechnology which lack any publications or patents. This limitation reflects the nonavailability of any robust open-access database of nanotechnology SMEs. Hence, we undertook the considerable effort required to develop our own database by joining multiple existing sources together (in this case, Web of Science, Derwent Innovations Index, PatStat, and Dun and Bradstreet) (Youtie et al. 2012). Due to limitations in our resources for collecting yet more information, we have not been able to include some variables of potential interest, such as international collaboration and the number of PhD scientists employed which might have an influence on publications by the firms. Information for such variables might be obtained through survey and other methods. Hence, there is certainly an opening for future research to expand upon our work with a larger set of records (in nanotechnology or in other fields) that incorporates other information (in addition to patents, publications, and core business descriptions) and which tests alternative methods of variable operationalization.

Using the available data, we found that the likelihood to publish and the number of publications by nanotechnology SMEs were both strongly associated with the greater use of public science – measured as a higher percentage of non-patent literature references in firms' patents. We found weak evidence associating a larger amount of publications with fewer technology factors covered by patents. This finding about the relationship between publishing and fewer technology factors indicates that if SMEs are working in an area that involves fewer technology factors, the area is potentially less complex, and SMEs are willing to publish. If the technology is more radical, involving more technology factors, then SMEs appear less willing to be open about these more complex findings.

We have not been able to establish a relationship between publications and external collaborators. This lack of a relationship is surprising, particularly given the attention raised in the literature to how external relationships with universities relates to reputational impacts. To some extent, this finding is consistent with the lack of a reputational association between nanotechnology firms and university researchers with enlarged social capital networks or reputational capital found in Wang and Shapira (2012), although that study did find that collaboration with highly productive university researchers increased the likelihood of an SBIR award. One could contend that the notion of seeking to draw on another organization's reputation through co-publishing does not seem to be strongly substantiated. However, it might also be the case that measuring collaboration with universities through co-patenting might not in itself cover the large variety of underlying activities between universities and SMEs, including joint research projects, research contracting, and other interactions with university scientists and students. To fully understand this issue, future research might examine relationships between SME publishing and alternative measures of external collaboration. This further work could also consider how reputational mechanisms might be influenced by characteristics of the nanotechnology domain through case study of specific nanotechnology SMEs or through testing and comparing results from other technology and industry domains.

In Hicks (1995)'s paper on corporate publications in science, it is argued that corporations strategically manage the ways to deal with the knowledge generated by R&D, i.e. to publish, patent, or keep it secret. Our findings lend support to such a strategic approach to publishing. Based on the evidence presented here in our study of nanotechnology SMEs, we propose that smaller technology firm publication strategies involve a two-stage decision-making process. The primary decision to publish or not is based on the company's need for sources of knowledge, specifically the company's intensity of using public science in its industrial innovation. After the company decides to publish, the relative difficulty in publishing is a secondary driver for deciding the amount of publications. At this level, publishing in an established area or having relationships with universities might have mediating effects, particularly as university researchers are themselves under increasing institutional pressure to publish papers. We find that the technology SMEs in our study have a tendency to publish in relatively established areas of inquiry. Such a tendency could be interpreted strategically in two ways: publications in established areas are easier get accepted and reflect the SME existing capabilities, or SMEs might have concerns in protecting (by not publishing) their most novel and potentially profitable innovations. In future work this two-stage decision-making model of a small firm's strategic management of publishing/non-publishing could have the potential to incorporate more details about firms' strategic motivations interacting with diversified environments to produce intellectual property and commercial outcomes.

We also find evidence supporting the hypothesis that nanotechnology is transitioning from discovery to application (Shapira et al. 2011). We do not find a decrease over time in firms' preferences to publish even after controlling for potentially-related variables. Additionally, the broad shift in choices between publications and patents seems best explained by the decline of non-patent literature citation in patents over time. This lesser use of science in patented innovations suggests that industrial R&D in later period has moved away from activities exploring general knowledge ("discovery") towards development of specific, industrial knowledge ("innovation"). In sum, the ability of SMEs to use open routes of scientific exploration may eventually payoff in terms of patent applications.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 0937591 through the Center for Nanotechnology in Society (CNS-ASU).

References

Acs, Z.A., & Audretsch, D. B. (1990). *Innovation and small firms*. Cambridge, MA: MIT Press

Adams, S., & Henson-Apollonio, V. (2002). *Defensive publishing: A strategy for maintaining intellectual property as public goods*. Briefing Paper No. 53, International Service for National Agricultural Research (ISNAR), The Hague: The Netherlands. http://www.cgiar.org/www-archive/www.cgiar.org/pdf/cas_ip_defensive%20publishing%20bp-53.pdf (accessed December 26, 2014).

Allen, R. C. (1983). Collective invention. *Journal of Economic Behavior & Organization*, *4*(1), 1-24.

Almeida, P., & Kogut, B. (1997). The exploration of technological diversity and geographic localization in innovation: Start-up firms in the semiconductor industry. *Small Business Economics*, *9*(1), 21-31.

Campbell, E. G., Clarridge, B. R., Gokhale, M., Birenbaum, L., Hilgartner, S., Holtzman, N. A., & Blumenthal, D. (2002). Data withholding in academic genetics: Evidence from a national survey. *Journal of the American Medical Association*, *287*(4), 473-480.

Chesbrough, H.C. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Boston, MA: Harvard Business School Press.

CNS-ASU (2014). *The Center for Nanotechnology in Society, Arizona State University*. https://cns.asu.edu/ (accessed December 26, 2014).

Cockburn, I. M., & Henderson, R. M. (1998). Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery. *The Journal of Industrial Economics*, *46*(2), 157-182.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. *The Economic Journal*, *99*(397), 569-596.

Criscuolo, P., Salter, A., & Ter Wal, A. L. J. (2014). Going underground: Bootlegging and individual innovative performance, *Organization Science*, *25*(5), 1287-1305.

De Fraja, G. (1993). Strategic spillovers in patent races. *International Journal of Industrial Organization*, *11*(1), 139-146.

Eaton, B. C., & Eswaran, M. (2001). Know-how sharing with stochastic innovations. *Canadian Journal of Economics*, *34*(2), 525-548.

Freeman, C. (1991). Networks of innovators: A synthesis of research issues. *Research Policy*, *20*(5), 499-514.

Gambardella, A. (1992). Competitive advantages from in-house scientific research: The US pharmaceutical industry in the 1980s. *Research Policy*, *21*(5), 391-407.

Harhoff, D. (1996). Strategic spillovers and incentives for research and development. *Management Science*, *42*(6), 907-925.

Harhoff, D., Henkel, J., & Von Hippel, E. (2003). Profiting from voluntary information spillovers: How users benefit by freely revealing their innovations. *Research Policy*, *32*(10), 1753-1769.

Hicks, D. (1995). Published papers, tacit competencies and corporate management of the public/private character of knowledge. *Industrial and corporate change*, *4*(2), 401-424.

Kay, L., Newman, N., Youtie, J., Porter, A. L., & Rafols, I. (2014). Patent overlay mapping: Visualizing technological distance. *Journal of the Association for Information Science and Technology*, *65*(12), 2432-2443.

Kay, L., Youtie, J., & Shapira, P. (2014). Signs of things to come? What patent submissions by small and medium-sized enterprises say about corporate strategies in emerging technologies. *Technological Forecasting and Social Change*, *85*, 17-25.

Koza, M. P., & Lewin, A. Y. (1998). The co-evolution of strategic alliances. *Organization Science*, *9*(3), 255-264.

Lenoir, T., & Lécuyer, C. (1995). Instrument makers and discipline builders: the case of nuclear magnetic resonance. *Perspectives on Science*, *3*, 276-345.

Lim, K. (2009). The many faces of absorptive capacity: Spillovers of copper interconnect technology for semiconductor chips. *Industrial and Corporate Change*, *18*(6), 1249-1284.

Liu, C.C., & Stuart, T. (2014). Positions and rewards: The allocation of resources within a science-based entrepreneurial firm. *Research Policy*, *43*(7), 1134-1143.

Lux Research. (2007). *The nanotech report 2006: Investment overview and market research for nanotechnology*. New York, NY: Lux Research.

McMillan, G. S., Narin, F., & Deeds, D. L. (2000). An analysis of the critical role of public science in innovation: the case of biotechnology. *Research Policy*, *29*(1), 1-8.

Merton, R. K. (1957). Priorities in scientific discovery: A chapter in the sociology of science. *American Sociological Review*, 22 (6), 635-659.

Meyer, M. (2000). Does science push technology? Patents citing scientific literature. *Research Policy*, *29*(3), 409-434.

Mody, C. C. M. (2006). Corporations, universities, and instrumental communities: Commercializing probe microscopy, 1981-1996. *Technology and Culture*, 47 (1), 56-80.

Morrison, P. D., Roberts, J. H., & Von Hippel, E. (2000). Determinants of user innovation and innovation sharing in a local market. *Management Science*, *46*(12), 1513-1527.

Mowery, D. C. (2011). Nanotechnology and the US national innovation system: Continuity and change. *The Journal of Technology Transfer*, 36(6), 697-711.

Muller, P., & Pénin, J. (2006). Why do firms disclose knowledge and how does it matter? *Journal of Evolutionary Economics*, *16*(1-2), 85-108.

Murray, F. (2002). Innovation as co-evolution of scientific and technological networks: Exploring tissue engineering. *Research Policy*, *31*(8-9), 1389-1403.

Nelson, R. (1962). The link between science and invention: The case of the transistor. In: *The Rate and Direction of Inventive Activity: Economic and Social Factors*. New York: National Bureau of Economic Research, 549-584. http://www.nber.org/chapters/c2141.pdf (accessed December 26, 2014).

Pavitt, K. (1998). Technologies, products and organization in the innovating firm: What Adam Smith tells us and Joseph Schumpeter doesn't. *Industrial and Corporate Change*, *7*(3), 433-452.

PCAST (2005). The National Nanotechnology Initiative at five years. Washington, DC: President's Council of Advisors on Science and Technology, Executive Office of the President. http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nni-five-years.pdf (accessed December 26, 2014).

Rogers, J. D., Youtie, J., & Kay, L. (2012). Program-level assessment of research centers: Contribution of Nanoscale Science and Engineering Centers to US Nanotechnology National Initiative goals. *Research Evaluation*, 21(5), 368-380.

Rosenberg, N. (1990). Why do firms do basic research (with their own money)? *Research Policy*, *19*(2), 165-174.

Rosenberg, N., & Nelson, R. R. (1994). American universities and technical advance in industry. *Research Policy*, *23*(3), 323-348.

Rubin, S. (2011). Do NOT publish that article (if you care about patent rights in the United States). *IEEE-USA Today's Engineer*. http://www.todaysengineer.org/2011/Dec/Patent-Law.asp (accessed March 25, 2013).

Shapira, P., & Wang, J. (2010). Follow the money. What was the impact of the nanotechnology funding boom of the past ten years? *Nature*, *468*, 627-628.

Shapira, P., Youtie, J., & Kay, L. (2011). National innovation systems and the globalization of nanotechnology innovation. *The Journal of Technology Transfer*, *36*(6), 587-604.

Simeth, M., & Raffo, J. D. (2013). What makes companies pursue an open science strategy? *Research Policy*, *42*(9), 1531-1543.

STIP (2014). Georgia Tech Georgia Tech Program in Science, Technology and Innovation Policy. http://stip.gatech.edu/ (accessed December 26, 2014).

Stephan, P. E., & Everhart, S. S. (1998). The changing rewards to science: The case of biotechnology. *Small Business Economics*, *10*(2), 141-151.

Stephan, P. E., & Levin, S. G. (1996). Property rights and entrepreneurship in science. *Small Business Economics*, *8*(3), 177-188.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, *15*(6), 285-305.

Thursby, J. G., & Thursby, M. C. (2002). Who is selling the ivory tower? Sources of growth in university licensing. *Management Science*, *48*(1), 90-104.

Verhees, F. J. H. M., & Meulenberg, M. T. G. (2004). Market orientation, innovativeness, product innovation, and performance in small firms, *Journal of Small Business Management, 42*(2), 134-154.

Von Hippel, E. (1987). Cooperation between rivals: Informal know how trading. *Research Policy,* 16:291–302

Von Hippel, E., & Finkelstein, S. N. (1979). Analysis of innovation in automated clinical chemistry analyzers. *Science and Public Policy*, *6*(1), 24-37.

Wang, J., & Shapira, P. (2012). Partnering with universities: A good choice for nanotechnology start-up firms? *Small Business Economics*, 38(2), 197-215.

Youtie, J., & Kay, L. (2014). Acquiring nanotechnology capabilities: Role of mergers and acquisitions. *Technology Analysis & Strategic Management*, *26*(5), 547-563.

Youtie, J., Iacopetta, M., & Graham, S. (2008). Assessing the nature of nanotechnology: Can we uncover an emerging general purpose technology? *Journal of Technology Transfer*, *33*(3), 315-329.

Youtie, J., Porter, A.L., Boyack, K., Lobo, J., Klavans, R., Rafols, I., & Shapira, P. (2012). Using large-scale databases to understand the trajectories of emerging technologies. In: Van Lente, H., Coenen, C., Fleischer, T., Konrad, K., Krabbenborg, L., Milburn, C., Thoreau, F. and Zülsdorf, T. (Eds.) *Little by Little: Expansions of Nanoscience and Emerging Technologies*. Heidelberg: IOS Press, 55-58.

Table 1 Publication and patenting by US large companies and SMEs in nanotechnology

	Patenting		Non-Patenting	
	Large Firms	**SMEs**	**Large Firms**	**SMEs**
Publishing	97	40	18	40
Not Publishing	10	45	0	0

Source: Georgia Tech Nanotechnology Corporate Panel (see text for further details). Analysis of sample of 125 US large firms and 125 US SMEs (small and medium-sized enterprises) who entered nanotechnology through publication or patents in the period 1990 to 2012.

Table 2 Comparison of publishing and non-publishing US SME nanotechnology firms.

	N	Papers	Patents	PNPL	UNIV	INDUS	TF
Publishing firms	40	1050	1932	0.18	0.04	0.08	6.3
Non-publishing firms	45	0	1067	0.14	0.05	0.14	7.6

Note: Analysis of 85 patenting nanotechnology SMEs in study sample. PNPL = average proportion of NPL citations per patent; UNIV = proportion of patents with university coassignees; INDUS = proportion of patents with industry coassignees; TF = average number of technology factors per patent (see text for further details).

Table 3. Descriptive statistics (observations are firm-periods)

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
PAPER	number of papers	146	7.19	20.39	0.00	52.00
PATENT	number of patent documents	146	20.54	27.35	1.00	157.00
PNPL	average proportion of NPL citations per patent	146	0.16	0.14	0.00	0.72
UNIV	proportion of patents with university coassignees	146	0.04	0.13	0.00	1.00
INDUS	proportion of patents with industry coassignees	146	0.11	0.23	0.00	1.00
TF	average number of technology factors per patent	146	7.02	5.17	1.00	26.00
PERIOD	a number sequence to represent three time periods	146	1.14	0.78	0.00	2.00
INVENTORS	average number of inventors per patent	146	3.84	1.93	1.00	11.50
Log(*PATENT*)	number of patent documents logged	146	2.24	1.32	0.00	5.06

Table 4 Regression outputs

PUB$_i$	(1) *PUBDUMMY* Coeff. (Robust SE)	Marg.	(2) *PUBCOUNT* Coeff. (Robust SE)	Marg.
UNIV	-0.39	-0.01	2.212*	0.137
	(0.067)		(-1.234)	
INDUS	0.004	0.001	-0.475	0.05
	(0.025)		(-0.763)	
PNPL	3.663**	0.909	4.160**	13.766
	(1.477)		(-1.871)	
TF	-0.052	-0.013	-0.099**	-0.462
	(0.443)		(-0.046)	
INVENTORS	-0.028	-0.001	-0.141	-0.617
	(0.103)		(-0.11)	
Log(*PATENT*)	0.436***	0.108	0.626***	2.12
	(0.165)		(-0.149)	
PERIOD	0.401	0.1	0.042	-0.135
	(0.257)		(-0.248)	
Constant	-0.17**		0.464	
	(0.685)		(-0.671)	
Number of observations	146		146	
Log-likelihood	-91.05		-333.8	

* p < 0.1. ** p < 0.05. *** p < 0.01.