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ABSTRACT

Scientific knowledge is believed to be the wellspring of innovation. Historically, firms have also invested in research to fuel innovation and growth. In this paper, we document a shift away from scientific research by large corporations between 1980 and 2007. We find that publications by company scientists have declined over time in a range of industries. We also find that the value attributable to scientific research has dropped, whereas the value attributable to technical knowledge (as measured by patents) has remained stable. These effects appear to be associated with globalization and narrower firm scope, rather than changes in publication practices or a decline in the usefulness of science as an input into innovation. Large firms appear to value the golden eggs of science (as reflected in patents) but not the golden goose itself (the scientific capabilities). These findings have important implications for both public policy and management.

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1. Introduction

Most would agree that modern economic growth is ultimately based in advances in science (Mokyr, 2002). Although universities and public research institutes are responsible for performing scientific research, in many industries the leading firms have also made significant contributions to scientific knowledge. Beginning with the German chemical firms in the 1880s, corporate research labs became more widespread in the 1930s, led by companies such as AT&T and DuPont. Scholars have argued that such investments have been a source of advantage to these firms (Griliches, 1986; Gambardella, 1995; Cockburn and Henderson, 1998). Corporations invested in science primarily to develop significant new products and processes, but also to help absorb external knowledge, and perhaps to attract talented workers.

However, since the 1990s, many leading firms have significantly reduced their investment in research.[1] Articles in the popular press lament the demise of top-flight corporate labs, crediting the rise of small research-intensive start-ups, often fuelled by venture capitalists (e.g., Economist, 2007). Other accounts blame the growing financial considerations that cloud the judgment of managers (Lazonick, 2013). Figure 1 shows that the share of research in the total non-federal investment in R&D, a rough approximation for the share of research in private R&D, has steadily declined since the 1990s.

[**Insert Figure 1 here**]

In this paper, we provide new evidence on the changing structure of corporate research. Over the period 1980–2007, we find that investments in scientific research by publicly traded American companies, as measured by publications in scientific journals by company scientists, has diminished over time. Moreover, the implied value of scientific capability has also declined. Specifically, we show: (i) a decline in publications by large American firms; (ii) a decline in the market value premium of the stock of publications; (iii) a fall in the acquisition premium paid for publications in M&A; and (iv) a decline in post-acquisition publication activity by target-firm scientists. By contrast, (v) patenting by firms has increased and (vi) the implied value patents, including the premium paid for patents in M&A, has remained stable, or perhaps even increased. These patterns are present across a range of industries, except biotechnology.

[1] For simplicity, we use the terms "science" and "basic research" interchangeably. This usage is not universally agreed upon, and with good reason. However, our choice is with an eye to the difficulty of empirically successfully distinguishing between scientific and basic research. When not likely to create confusion, we sometimes simply use "research" for brevity.

We interpret these patterns as part of a longer historical process wherein firms are specializing in different parts of the innovation value chain, with many large firms becoming less reliant on internal research and more reliant upon external inventions. Large firms continue to value the golden eggs of science (as reflected in patents, and in citations to scientific publications in patents) but not the golden goose itself (a firm's scientific capabilities). These patterns may also involve a greater emphasis on the "D" of R&D, and on short-term and incremental innovation, which often does not require large investments in science (e.g., Lazonick and Tulum, 2011).

A concern is that our results may merely reflect changes in how firms protect their knowledge. Large firms may still be investing in science but may be publishing less, perhaps in order to patent or better protect their research findings. In principle, the strengthening of intellectual property, particularly patents, should encourage rather than discourage firms from publishing (Gans, Murray, and Stern, 2013). But even if the firms are eschewing publication to avoid inadvertent disclosure of commercially valuable findings, we would expect that they would particularly avoid applied scientific journals. Applied journals are more likely to contain findings close to commercial applications. We find instead that the decline in firm publications is especially marked for publications in high-impact scientific journals, as well as in journals dedicated to basic rather than applied research. Moreover, provided that science remains valuable, changes in publication behavior should not affect the premium for scientific capability paid by acquiring firms in M&A, contrary to what we find. Overall, our results suggest that large firms are withdrawing from investing in science internally and focusing more on development (less "R" and more "D,") rather than simply changing their publication behavior.

Firms would reduce investment in science if science itself becomes less useful for innovation (Jones, 2009; Gordon, 2012). However, we do not see any decline in the number of patent citations to science over time, nor do we find any evidence that the science used in inventions is growing older. Thus, the decline in private investments in science cannot be explained away by a reduction in the usefulness of new science. The patterns in citations to scientific journals by patents also make it unlikely that our results are driven by reduced incentives to absorb external knowledge. There is substantial evidence that many large firms increasingly rely on external knowledge to fuel their growth (Arora and Gambardella, 1990; Arora, Fosfuri, and Gambardella, 2001; Higgins and Rodriguez, 2006; Mowery, 2009). A greater division of innovative labor should increase, not decrease, the incentives of large firms to invest in science for absorptive capacity purposes. Indeed, we find that firms with higher scientific capability cite more recent science in their patents, and this effect has not declined over time.

Although problems of appropriating the benefits of scientific research are well known, there is no evidence that these problems have worsened over time. If anything, stronger patent and copyright laws appear to have made scientific knowledge easier to protect. Nor do our findings reflect a purely American phenomenon, driven by idiosyncratic changes in American institutions. We find similar results for European firms (both public and private) that we matched with our patent and publication data.

We argue that lower investments in science by large firms likely reflect reduced incentives to develop significant new products and processes internally. Two pieces of evidence support this interpretation. First, increased global competition (as measured by changes in Chinese import penetration) is associated with reductions in investments in science, R&D expenditures, and physical investment, and a decline in the stock market value of publication stock. Interestingly, however, the propensity to patent increases, as does the stock market value of patent stock. These contrasting trends suggest that increased global competition is associated with a shift away from the creation of new knowledge and toward the commercial application and protection of existing knowledge.

Second, the decline in investments in science is also associated with narrowing firm scope. A famous conjecture in innovation studies is that investments in basic research are more profitable in diversified firms, either because of scope economies in research (Henderson and Cockburn, 1996) or because "[a] broad technological base insures that, whatever direction the path of research may take, the results are likely to be of value to the sponsoring firm" (Nelson, 1959: 302). Using firm-level data on sales concentration to measure firm scope, we find that moving from the lowest to the highest decile of decrease in firm scope is associated with a drop of 87 percent of the sample average in publications. Also, we find a decline in the stock market value of publications as firms narrow their scope. Thus, narrower firm scope may be an additional mechanism behind the decline in scientific capability of large firms.

Our findings have important implications for managers and policy makers alike. We find that scientific capability continues to be important for innovation but that large firms face lower incentives to develop significant new products and processes internally, and have reduced their investments in science. To some extent, they rely upon startups to develop new inventions. In turn, such startups themselves rely, at least in part, upon university research. The decline in public support for scientific research, manifest in tightening budgets at NSF and NIH, may therefore depress the production of new knowledge significantly.

This withdrawal of large firms from science has been accompanied by a growing division of innovative labor in which large firms focus on development and commercialization, leaving universities and small firms to generate new ideas (e.g., Arora and Gambardella, 1994). However, our results also suggest that small, science-intensive firms cannot simply rely on generating scientific knowledge and hope to be acquired. Because the rewards for pure scientific capability have diminished, these firms also have to invest in finding tangible commercial applications of their ideas. To the extent that universities and small firms are ill-equipped to undertake this more applied research, inefficiencies may result.

Our results also inform debates on the effects of competition and globalization on innovation. Research in the Schumpeterian tradition warns that competition may be detrimental to innovation because, by destroying monopoly rents, it may reduce the incentives to innovate (Schumpeter, 1942). On the other hand, the desire to escape the competition may induce incumbents to invest and innovate more (e.g., Aghion et al., 2005; Bloom et al., 2011). Our results indicate that both forces are at work, but for different types of research (basic versus applied). Competition may also be behind the narrowing scope of firms, which may reduce their incentives to invest in longer-term and more basic scientific research, while enhancing incentives to undertake more incremental, patentable research.

The remainder of the paper is organized as follows. Section 2 provides some historical and conceptual background for the empirical analysis, and relates our work to the existing literature. Section 3 discusses our data sources. Sections 4 to 7 describe our econometric specifications and present our estimation results. Section 8 discusses some of the implications of our findings, while Section 9 concludes.

2. Background

2.1. Evolution of corporate research and the division of innovative labor

Several institutions contribute to the advancement of science. Historically, universities and government-sponsored programs, such as the National Institutes of Health in the U.S., have been the most important. Despite the well-known problems in appropriating the benefits of investing in scientific research, firms have also invested in scientific research, and some corporate laboratories have made very significant contributions to science.

Corporate investments in science began modestly. The leading firms of the 1870s and 1880s, such as the railroad companies and Western Union, which relied heavily upon externally generated inventions, established industrial labs to evaluate the quality of inputs (Mowery, 1995; Carlson, 2013). Growing competition, anti-trust pressures, and the increasing output of university-trained PhDs led companies such as GE and DuPont to invest in internal research to generate new products and processes to create new markets and fuel growth (e.g., Hounshell and Smith, 1986). The process gained momentum during the inter-war years, as corporations grew larger and more anxious to control and "routinize" innovation. Landmark discoveries (e.g., synthetic rubber, nylon), the growing practical applicability of recently discovered scientific principles, and the rapid increase in government funding in the United States led to more companies investing in internal research after World War II.

But corporate research often failed to deliver returns to shareholders. Discoveries such as nylon and the transistor were few and far between. And even when fundamental advances in science or technology were made, the sponsoring firms often failed to profit from these advances (Teece, 2010). The graphical user interface, for instance, was invented in Xerox's PARC, but other firms, most notably Apple and Microsoft, reaped the rewards. By the 1980s, firms began to look to universities and small start-ups as sources of ideas and new products, using a mix of contracts, licenses, alliances, and outright acquisitions. Many corporate labs were closed, downsized, or redirected toward more commercial applications (Pisano, 2010). NSF data indicate that in 1985, firms with more than 10,000 employees accounted for 73 percent of non-federally funded R&D. By 1998, this share had dropped to 54 percent. By 2008, large firms accounted for 51 percent of company-funded domestic R&D. An additional indicator of the decline in the relative importance of large firms is the sharp drop in share of large firms in the R&D 100 awards winners: whereas 41 percent of the awards went to Fortune 500 firms in 1971, only 6 percent went to Fortune 500 firms in 2006 (Block and Keller, 2009).

Several factors contributed to the growing importance of small firms, particularly in science-intensive sectors. One is the more prominent role played by universities and other research institutions in the commercialization of science. The 1980 Bayh-Dole Act encouraged universities to more aggressively license and commercialize their discoveries, and scientists found it increasingly attractive to start their own businesses. The success of Genentech, a biotechnology company founded by biochemist and Nobel Prize–winner Herbert Boyer and venture capitalist Robert A. Swanson, showcased the potentially huge rewards associated with such a strategy. Also, start-ups' high-powered incentives were difficult to replicate in large, established firms, where bureaucracy, politics, and the burden of past legacies tend to thwart radical change (Schumpeter, 1942; Leibenstein, 1966;

Christensen and Bower, 1996; Sull et al., 1997). Changes in the institutional and legal environment have complemented these trends. Start-ups can get financing from venture capitalists and SBIR and other government programs (Kortum and Lerner, 2000; Lerner, 1999; Mazzucato, 2013). Intellectual property rights have been significantly strengthened starting from the early 1980s, first in the U.S. and subsequently in other countries (Jaffe and Lerner, 2004; Guellec and van Pottelsberghe de la Potterie, 2007). These developments have promoted a new division of labor, where small start-ups specialize in scientific research and larger, more established firms specialize in product development and commercialization (Arora and Gambardella, 1994).

2.2. Conceptual background and contribution to the literature

Typically, investments in scientific research are undertaken by firms to create new products or processes and to absorb outside technology. Innovations sometimes arise directly from scientific advance (e.g., new drugs), sometimes they arise as indirect outputs of scientific research (e.g., laser), and sometimes scientific research perform a very indirect role by enhancing the productivity of technical search, by guiding it toward more fruitful pastures (Evenson and Kislev, 1976, Gambardella, 1995; Fleming and Sorenson, 2004).

Investments in scientific research also help firms absorb outside technology (Cohen and Levinthal, 1989; Arora and Gambardella, 1994; Gambardella, 1992). Scientists can help identify promising new inventions, may engage with outside researchers who are creating new breakthroughs, and may help with assimilating and adapting outside technology. Publishing in academic journals and attending conferences, in particular, may be the most effective way to remain "plugged in" to the external scientific network (Rosenberg, 1990; Cockburn and Henderson, 1998).

Tracing the use of science in innovation is not easy. Narin et al. (1997) proposed using citations by patents to scientific publications as a proxy. We find that patents continue to cite science at the same rate as before, and the age of the cited publications is constant over time, indicating that new scientific discoveries continue to be relevant for innovation. Moreover, publishing firms cite more recent science than non-publishing firms, indicating that scientific capability continues to bestow an advantage in terms of being able to absorb more recent scientific findings.[2]

[2] Engaging in scientific activities also enhances the reputation of the firm and certifies the quality of its research to prospective investors, employees, government agencies, and sophisticated customers (Lichtenberg, 1988; Hicks, 1995; Audretsch and Stephan, 1996). Clinical studies, for instance, are routinely used by firms in the pharmaceutical industry to advertise the effectiveness of their drugs to doctors and hospitals (Azoulay, 2002). Also, to the extent that allowing employees to publish helps firms recruit more talented researchers, participating in the process of advancing science can be a profitable strategy for some firms (Stern, 2004; Roach and Sauermann, 2010). Our findings do not speak to these possible reasons for engaging in scientific research.

Many scholars have documented the benefits of investment in science. Griliches (1986) analyzes the drivers of productivity and profits for a sample of the 1,000 largest manufacturing firms in the U.S. For the period 1957–1977, he finds that the share of basic research in the firm's R&D expenditure was positively related to measures of productivity growth. Hall, Jaffe, and Trajtenberg (2005) use a market value approach to measure the return to R&D investment for U.S. firms in the 1980s. Koenig (1983) finds the drug output of large pharmaceutical companies is positively related to their publication output (especially highly cited clinical articles). In 10 science-intensive technological domains, Van Looy et al. (2003) find a positive relationship between the science intensity of patents (i.e., the citations to the scientific, non-patent literature) and technological productivity. A positive relationship can also be found between the market valuation of firms and the science intensity of their patents (Deng, Ley, and Narin, 1999) or their stocks of scientific publications (Simeth and Cincera, 2013).

We extend these studies by including data from a later period and by focusing on smaller firms, which appear to be an increasingly important location for private-sector research. Consistent with Griliches (1986), we find that a positive private value for scientific capabilities, but that in the latter part of our sample, this valuation has fallen considerably. Also, in addition to stock market value for publicly held corporations, we use acquisition price for Thomson SDC Platinum target firms. This allows us to examine the value of scientific capability for firms that get acquired, which are often small and privately held.[3]

Industry studies have also documented the benefits to investments in science. In the pharmaceutical industry, strong correlations between measures of connectedness with the wider scientific community and firms' internal organization and performance in drug discovery have been documented by Cockburn and Henderson (1998). Meoli, Paleari, and Vismara (2013) analyze a sample of 254 biotech firms that went public in Europe between 1990 and 2009. They find that university-affiliated firms received a premium and were more likely to be targets of M&A activity after going public. Simeth and Cincera (2013) also find that the market value of publicly traded firms in high-tech is positively related to publication stock for the period 1990–2003.These studies do not examine how the implied value of investments in science has changed over time.[4] We use data on both publication output and the implied stock market value of the stock of publications for a much larger sample of all publicly traded American firms and verify that similar patterns hold for

[3]Another difference with Griliches (1986) is that we primarily use the stock of scientific publications to measure scientific capability, consistent with Gambardella, (1992), Arora and Gambardella (1994) and Cockburn and Henderson (1998).

[4]However, Simeth and Cincera's (2013) results also imply a decline in the value of publications.

European firms. We additionally use data on acquisitions of small, research-based firms to infer the implied value managers place on scientific capability in the target firms.

Yet, despite the potential benefits, managing scientific research inside a firm is difficult. There are well-known problems with appropriating the results of scientific discoveries. Even when patents are effective, research, as opposed to development, tends to involve projects with long time horizons and uncertain outcomes. Choosing suitable research projects, providing researchers with appropriate goals, and monitoring their performance is difficult, especially for managers whose expertise is commercial rather than scientific (see Kay, 1988). Investments in research are more productive when researchers have creative freedom and operate in an "open,"university-like institutional arrangement (e.g., Dasgupta and David, 1994). Often this requires insulating research from the rest of the business. Such isolation from the business can result in corporate research diverging from the firm's strategic needs, making it less relevant to the firm (Hounshell and Smith, 1986; Argyres and Silverman, 2004, Arora et al., 2014).

A related literature deals with the institutional arrangements for "open science"inside profit-oriented firms. (e.g., Dasgupta and David, 1994; Murray, 2004; Gans et al., 2013). This literature highlights a key trade-off between value creation (which is enhanced by allowing free reign to the creativity of researchers) and the need for appropriation (e.g., Stern, 2004; Patacconi et al., 2012). Our findings suggest that many of these questions may become moot for large firms.

The difficulty of managing research in large firms suggests a division of innovative labor between established firms and smaller firms and start-ups (Jewkes, Sawers, and Stillerman, 1969; Arora et al., 2001). In this view, smaller firms have a comparative advantage in generating ideas whereas larger firms have an advantage in exploiting them. Large firms may invest in scientific capability to be effective buyers of knowledge. Arora and Gambardella (1994) argue that scientific capability (as measured by publication stock) enables pharmaceutical firms to be more discerning in sourcing innovations from biotechnology firms. The division of innovation labor often involves innovations being transferred through acquisitions. A few papers focusing on M&A stress the difficulties acquirers face in making productive use of knowledge assets they buy, particularly of the human capital they acquire in the form of inventors and researchers. For instance, Valentini (2012) concludes that acquisitions in medical devices and photographic equipment between 1988 and 1996 resulted in a greater focus by the acquirer on short-term results. Consistent with this, we find that scientists who move to large firms after an acquisition have progressively reduced publication over time.

Finally, our paper speaks to the long-standing debate on competition and incentives to innovate.

Schumpeter (1942) famously argued that perfect competition may not be the market structure most conducive to innovation because lower price-cost margins may discourage investments in R&D. On the other hand, successful innovation may be the most effective way to "escape" competition and low price-cost margins (e.g., Aghion et al., 2005). Empirical work on the topic, while extensive, has been largely inconclusive (see Cohen 2010 for a survey). Bloom et al. (2011) use a panel of up to half a million firms over 1996–2007 across twelve European countries, and find that Chinese import competition led to increases in patenting, IT, and TFP. For a smaller sample of 459 R&D-performing firms, they also find that Chinese import competition led to an increase in R&D. We confirm Bloom et al.'s finding that greater Chinese import penetration is associated with an increase in patenting. However, we also find that competition from China is associated with *reductions* in investments in science, R&D expenditures, and physical investment. These findings suggest that low-cost competition may have different effects depending on the type of activity. It may encourage incremental and appropriable (i.e., patentable) research, but may discourage more long-term, basic research.

3. Data

We combine data from five main sources: (i) U.S. Compustat, (ii) M&A data from Thomson SDC Platinum, (iii) scientific publications from ISI Web of Knowledge, and (iv–v) patent data from PatStat (USPTO and EPO). We use three different firm samples. Our principal results pertain to publicly traded firms in the U.S. We also provide additional evidence using a large sample of M&A deals and public and private European firms. The latter two samples are described in more detail along with the corresponding empirical results.

We focus our econometric analysis on U.S. Compustat firms with at least one patent over the period 1975–2007, leaving us with 1,014 firms and 11,304 firm-year observations. To capture their investment in science, we match these firms to ISI Web of Science (matching firm name with the affiliation field for each publications record). We identify 312K publications with at least one author employed by a Compustat firm in our sample. To measure investment in technology, we match our firm sample to patents granted by U.S. and European patent offices from PatStat. To avoid double counting of patents on the same invention, we exclude European patents that belong to the same family as an already matched U.S. patent.

The main variables used in the analysis of Compustat firms include market value, book value of capital, R&D stock, publications stock, and patents stock.[5] Panel A in Table 1 summarizes descriptive statistics for Compustat firms. The mean market value of the firms in our sample is $5.9 billion (of which $3 billion are in physical assets), and average R&D spending is $129 million. Their scientific publications stock is 58 and patents stock is 174. Approximately 28 percent of our sample firms publish a scientific article at least once during the sample period.

[**Insert Table 1 here**]

4. Investment in Science and Technology Over Time

Figures 2–4 plot the data patterns of investment in science and technology over time. These figures do not account for changes in sample composition over time. Later in the econometric analysis we present the corresponding within-firm analysis that accounts for changes in sample composition.

Figure 2 reports on Compustat firms with at least one year of positive R&D expenditures for the period 1980–2007. Consistent with the broad trend reported in Figure 1, Figure 2 shows that large American firms are reducing their investment in science whereas their investment in R&D more broadly has not decreased, and their patenting output has increased. The share of firms that publish each year has dropped over time from a high of 30 percent in 1980 to a low of close to 10 percent in 2007. On the other hand, the share of patenting firms has increased over time from 20 percent in 1980 to just under 30 percent in 2007. R&D intensity (R&D over sales) has also been rising from 1 percent in 1980 to 2 percent in the mid-90s.

Figure 3 presents time trend in outsourcing of science and technology. For publishing firms, we plot the percentage of firms that acquire at least one publishing firm in the given year, and for each patenting firm we plot the percentage of firms that acquire at least one patenting firm in the given year. Both these percentages are rising steadily, consistent with the view of technological outsourcing is rising over time. Note that we do not measure other ways, such as contract research or licensing, through which firms can outsource research.

Outsourcing of research can potentially offset the decline in investment in science by large firms.

[5] Following Griliches (1986), market value is defined as the sum of the values of common stock, preferred stock, and total debt net of current assets. The book value of capital includes net plant, property and equipment, inventories, investments in unconsolidated subsidiaries, and intangibles other than R&D. R&D stock is calculated using a perpetual inventory method with a 15 percent depreciation rate (Hall et al., 2005). So the R&D stock, GRD, in year t is $GRD_t = R_t + (1 - \delta)GRD_{t-1}$ where R_t is the R&D expenditure in year t and $\delta = 0.15$. Publications stock in year t is calculated in the same way as $Publications\ stock_t = Pub_t + (1 - \delta)Publications\ stock_{t-1}$ where Pub_t is the citations-weights flow of publications in year t. Citation weights are the ratio between the number of citations an article receives and the average number of citations received by all articles published in the same year. Patents stock is computed in an equivalent way using patents data.

However, as Figure 4 shows, even after combining internally generated publications with those that are acquired, we still see the pattern declining investment in science as in Figure 2.

[Insert Figures 2–4 here]

5. Econometric Results

5.1. Internal investment in science

Columns 1–3 in Table 2a present the estimation results of time trends in investment in science using within-firm specifications. We report robust standard errors and cluster by firm. Publication intensity (number of publications, weighed by citations received, over R&D stock) clearly falls over time. The estimates imply that between 1980 and 2007, publication intensity fell by 66 percent of average sample value. We find a similar trend for patents (column 2), but not for R&D intensity (R&D expenditures over sales), which remains stable over time. While our within-firm estimation controls for changes in the sample composition over time, our results can still be driven by younger firms that entered the sample in the second half of our sample. To check the robustness of our results to this concern, we also explored specifications where we restrict our sample to firms that are present in both early and late sample periods. The results remain robust.[6]

These changes in publication output could reflect either a reduction in the private value of scientific capability or an increase in the marginal cost (or both). An increase in marginal cost would reduce the quantity of research but also increase its average value. To distinguish between shifts in value or cost, we estimate a Tobin's q–type equation. We examine how the elasticity of market value with respect to publication and patent stocks has changed over time. Column 4 includes interactions between publication stocks with a time trend, as well as between patent stocks and time trend. We cluster standard errors by firm, and include 248 four-digit industry fixed effects. The coefficient estimate on the interaction between publication stock and time trend is negative and statistically highly significant. Based on these estimates, between 1980 and 2007, the elasticity of market value with respect to publication stock dropped from 0.074 to 0.02. For patents, the elasticity rose from 0.066 in 1980 to 0.182 in 2007. Columns 5–6 split the sample at its median year to allow for a more flexible analysis of how the coefficient estimates change over time. The same pattern of results holds. In unreported specifications, we find that our results are also robust to

[6] For example, for firms that are in our sample for at least 20 years, the coefficient estimate on time trend is -0.030 (a standard error of 0.009). For firms that are present at least 10 years, the coefficient estimate is -0.038 (a standard error of 0.006).

the exclusion of the dot com bubble years. Specifically, the exclusion of the period 1998-2000 does not materially change our results.

Interpreting estimates from market value regressions is not straight forward. Our interpretation is that the decline in publishing output reflects a reduction in the derived demand for private investment in scientific research. Taken together, the results in Table 2a imply that the decline in publication output is not merely a matter of possibly higher marginal cost of research but instead reflects a reduction in the "demand" for scientific capability. The results imply that whereas the private value of technical capability has increase (or, at a minimum, has not decreased), scientific capability has become privately less valuable.

[Insert Tables 2a and 2b here]

5.2. Publication output as a measure of investment in science

Scientific publications are a common measure of investments in basic research and hence of the accumulated scientific capability of the investing firm. However, it is possible that our results simply reflect changes in publication behavior. For instance, stronger intellectual property rights may induce firms to keep their scientific discoveries secret and to rely more heavily on patents. If firms have changed publication practices, scientific publications may become a less accurate measure of scientific capability. To investigate this possibility, we separate trends in company publication by the type of journal. Insofar as companies change publication strategy to be able to patent their research findings or to avoid information leakage, we would expect publications in applied journals to decline faster than those in basic research journals. This is because applied journals are more likely to contain commercially sensitive and patentable information. As Table 2b shows, we find the opposite.

For the results reported in Table 2b, we match all journals in our data to the CHI journal database (Leten, Kelchtermans, and Belderbos, 2010, Keltcherman, Leten, and Belderbos, 2011). The complete CHI database includes a list of 17,753 journals which have been classified by their level of research "basicness". About 40 percent of the publications in our sample were matched to CHI journals. Columns 1 and 2 distinguish between firm publications in basic and applied journal. A publication is classified as *basic* if it is published in a journal with a CHI level of 4 (the highest value), and as *applied* if it is published in a journal with a CHI level of 1 (the lowest level). We find that the decline in publications over time (within firms) is strongly evident for basic publications, but not for applied publications. This suggests that the decline in publications documented in Table

2a is driven by a decline in basic research. Column 3 examines the time trend in the share of firm publications in basic journals (CHI level of 4), for the subsample of publishing firms. We find that the share of basic publications in total firm publications has fallen over time.

Columns 4–5 present the estimation results for stock market value. Column 4 includes separate measures for basic and applied publication stocks. The decline over time in the elasticity of value with respect to publications is evident for basic publications (an estimate of -0.019), but not applied publications (an estimate of 0.001). Column 5 focuses on the subsample of publishing firms and shows that the elasticity of firm value with respect to the share of firm publications in basic journals is positive and quantitatively large (an estimate of 0.051), and that this elasticity has fallen in value over time. Finally, in unreported regressions we find that all these results hold also when we use the journal impact factor as our measure of publication quality, instead of classifying publications by the CHI index.

In sum, Table 2b shows that firms are publishing less largely because they are publishing less basic research rather than publishing less applied research. Further, the decline in the value of scientific capability is largely because basic scientific capability is less valuable. These patterns are inconsistent with the notion that the decline in publication reflects mere changes in publication behavior. Rather, large firms appear to have changed their R&D composition—they have been moving away from basic research and toward more applied/patentable research.

5.3. Patterns within technology domains

Tables 3–4 explore how the above patterns of results vary across industries. We classify firms into technology areas based on the distribution of their patents across the following technology fields: biotechnology, chemicals, pharmaceuticals, electronics, information technologies, semiconductors, and telecommunications. Overall, we find that the trends reported in Table 2a are present in all technology domains. In Table 3, we interact a time trend with technology dummies. Column 1 shows that publication intensity falls in all technologies. The rate of decline varies and the decline is steeper in pharmaceuticals, IT, and semiconductors compared to chemicals and biotechnology. Table 4 examines the relationship between scientific capability (measured as the stock of publications) and firm value. As in Table 2a, it shows that the implied private value of scientific capability has declined in all technology domains except biotechnology. The principal takeaway from Tables 3–4 is that the decline in research that we have documented is broad based, and not driven by any particular technology domain.

[Insert Tables 3–4 here]

5.4. Value of scientific capability in M&A

Our estimates of the private value of scientific capability rely upon stock market values. These reflect the collective judgment of investors. Managers, on the other hand, allocate resources to invest in science and technology. We use the prices that firms in our sample pay to acquire other firms to confirm that the implied value that managers put on scientific capability have also fallen over time. Our sample includes all deals from SDC Platinum with non-missing acquisition price, percentage of acquired equity, assets and sales. From the M&A listed in SDC Platinum, we select acquisition deals that provide information on deal value, net total assets and acquired stakes, and restrict the sample to targets from OECD countries. We match SDC Platinum firms to ISI and PatStat to develop measures of the publication and patents of the target firms. Our estimation sample includes 29,752 deals. Of the acquired firms, 46 percent are American and 19 percent are British. The vast majority of our sample of acquirers are publicly listed (96%), and about half of them are American. Prior to the acquisition completion year, 971 target firms have at least one academic publication and 4,174 firms have at least one patent.

Panel B in Table 1 above summarizes the descriptive statistics for target firms. The average target firm is valued at $162 million, has $79 million in assets, generates $138 million in annual sales, and makes $17 million in profits. Of the target firms that have at least one publication, the mean stock of publications is about 4 with a median value of 0.2. Of the target firms with at least one patent, the mean stock of patents (the sum of USPTO and EPO patents) is 30 with a median value of 3.6.

Table 5 presents the estimation results for the value of scientific capability based on acquisition price. The estimation results are consistent with the stock market regressions. Column 1 interacts publication and patent stocks with time trend. Consistent with our previous findings, the elasticity of acquisition price with respect to publication stock is falling over time. On the other hand, the elasticity of acquisition price with respect to patent stock is rising, albeit much less than what we found in the sample of publicly traded (Compustat) firms.

Columns 2–3 use more flexible specifications which split the sample at the median year value. As before, the coefficient estimate on publication stock is very large and statistically significant in the early sample period (0.169), and falls to zero in the later sample period (-0.043). We easily reject the null hypothesis that these two coefficients are statistically identical. Column 4 shows that the same pattern of results continues to hold when we restrict the sample to target firms that either patent (USPTO or EPO) or publish. Column 5 shows that the results are not driven by the 1999–2001 IT bubble.[7]

The main takeaway from Table 5 is that the value managers place on scientific capability of their target firm (as proxied by its stock of publications) has fallen over time whereas the value they place on the technical capability of their target firm (as proxied by its stock of patents) has not decreased. This is broadly consistent with the conjecture that large firms are shifting their focus away from basic research and toward more applied activities.

[Insert Table 5 here]

5.5. Post-acquisition publication behavior

If the value of scientific capabilities has declined and acquiring firms are becoming more reluctant to harbor internal science, we would expect to see a decline in publication activity by researchers of the target firms after the acquisition. Measuring post-acquisition publication activity is challenging because the acquired firm may cease to exist as an independent unit following the acquisition. To account for publications of potentially dissolved units, we include publications by acquiring firms in the post-acquisition period where the authors also appear on pre-acquisition publications belonging to the acquired firm. We follow the same procedure when constructing the flow of post-acquisition patents.[8] If large firms are withdrawing from science, then the scientists who are hired through acquisitions should reduce their publication activity post-acquisition, and the reduction should be larger for more recent acquisitions.

Table 6 presents the estimation results of a within-firm variation in publication behavior post-acquisition. For each firm, we examine a three-year window around the acquisition year and estimate the effect of a post-acquisition dummy—a dummy that receives the value of one for the three post-

[7] It is possible that the sample of acquired firms has changed over time, either due to better coverage by SDC or because of improvements in M&A institutions. Improved coverage or lower transaction costs for M&A can result in more marginal targets being acquired. Thus, one might expect lower valuations for intangibles. As shown in Table A1, Tobin's q values do not vary substantially over time, inconsistent with the coverage of lower quality acquisitions over time. To further test this concern, we re-estimated our baseline specifications from Table 4 by removing acquisitions in the upper and lower percentile of the Tobin's q distribution. The results remain robust, which is again inconsistent with the concern that acquisitions with lower Tobin's q became more prevalent toward the end of the estimation period due to better coverage by SDC. Furthermore, concerns about lower valuation should result in lower intercept terms, not necessarily a downward bias in the coefficient of publications (or of the other measures of scientific capability). Indeed, we find no decline in the coefficients of patent stock, net assets, or sales. Thus, it is unlikely that our findings are driven by changes in the composition of the sample of acquired firms over time.

[8] We use a three-year window to track publications after acquisition by the target firm. Around 90 percent of the publications continue to carry the name of the acquired firm, but about 10 percent of the post-acquisition publications are in the name of the acquiring firm but with an author who appears on a previous publication of the target firm.

acquisition years and zero for three pre-acquisition years. Columns 1–6 present the estimation results for the flow of publications. Column 1 shows that publications tend to drop post-acquisition. Comparing columns 2 and 3, we see that the drop is especially marked for acquisitions in the second half of our sample period: The coefficient on the post-acquisition dummy falls from 0.013 for acquisitions between 1985 and 1996, to -0.198 for acquisitions between 1997 and 2004. The difference is statistically significant and meaningful. Whereas there is very little decline in publication post-acquisition in the early part of the sample period, for later deals, after-acquisition publications drop by about 33 percent of the sample mean.

This pattern of results also holds when we weigh publications by citations (the coefficient estimate on publications flow drops from a positive 0.9 in the first sample period, to a negative -1.8 in the later sample period). For deals after 1997, the post-acquisition publication decline is 27 percent.

Columns 7–9 report the same analysis for patents. We find that on average, patenting activity rises after the firm has been acquired. However, this rise takes place mostly in the first half of the sample, while in the second half there is no change in patenting activity post-acquisition.

In sum, Table 6 provides additional support for the conjecture that firms have lowered their willingness to pay to acquire external scientific capability over time. In part, at least, this is because the acquiring firms are less willing to invest in science internally. The fruits of scientific capability, patents, continue to be valued but scientific capability itself is not.

[**Insert Table 6 here**]

6. Mechanisms

6.1. The use of science in innovation

Firms invest in science for several reasons. One key reason is that scientific discoveries may themselves lead to innovation. If new scientific knowledge is becoming less relevant for commercial innovation, firms will be less likely to invest in research. Tracing the application of science to commercial ends is very difficult. One proxy, admittedly highly imperfect, is the citations patents make to scientific publications. Narin et al. (1997) pioneered the use of this measure to show that U.S. patents relied upon publications by public and for-profit institutions. They found that, of the papers published in 1988 cited by patents issued in 1993, over 40 percent were from public research institutes, while nearly 27 percent were produced by firms. If applying scientific knowledge to industry is becoming much harder or more costly, there ought to be fewer citations to science by patents.

Table 7 presents the estimation results for within-firm OLS specifications for number of patent citations to science. Because we are interested in patent citations to science, we exclude references to journals that are not considered scientific. We also remove publications in trade journals and conference proceedings.[9] As shown in column 1, patent citations to science remain stable over time. Columns 2 and 3 split the sample by firms that invest in science and firms that do not. For both subsamples we find an insignificant coefficient estimate on time trend. Columns 4–7 explore variation across broad technology fields. No field experiences a decline in the number of citations to science over time. In unreported regressions, using either market value or acquisition value, we find that the decline in the value of scientific capability is robust to controlling for the share of references to science. Consistent with this, NSF data show that whereas about 10.6 percent of U.S. utility patents cited scientific publications in 1998, the share had increased to 11.9 percent by 2010. Over the same period, the share of scientific publications cited in a patent had largely remained unchanged, at around 1.7 percent (NSF S&E Indicators, 2012, Table 5-49).

[Insert Tables 7–8 here]

Though patents may continue to cite science, perhaps they are citing older science. If innovation is less likely to require new scientific knowledge, firms may reduce their own investment in creating such new knowledge. Further, investments in scientific capability may serve to absorb and use existing scientific knowledge, the vast bulk of which is external to the firm. If, over time, external scientific knowledge has become more accessible to firms due to developments in markets for technology and improvements in information technology, the need to invest in scientific capability may have fallen.

We explore the empirical support for these ideas by examining trends in whether innovations rely upon increasingly older scientific knowledge, and how this differs with the scientific capability of the firm. Specifically, we ask if the average age of scientific publications cited by patents has changed over time, and whether these trends differ between firms that do publish and those that do not. We expect that if innovation is less reliant upon recent scientific knowledge, the average age of the publications cited by patents should increase. If scientific capability enables firms to use more recent science in their innovations, this should be reflected in a lower average age of publications

[9] As robustness checks, we also excluded references to articles that are not published in journals in the CHI journal database. In the "clean" sample, mean patent citations to science at the firm-year level is 2.4 (a median of 0.5). As an additional robustness check, we reran estimates restricting our attention to citations to journals with a high (above median) ISI impact factor. We find results very similar to those reported in the paper. Our results are also not sensitive to whether the cited article is coauthored with a university scientist.

cited by their patents That is, publishing firms should cite more recent publications in their patents than non-publishing firms. However, if scientific capability is less relevant for absorbing external knowledge, the difference in the vintage of articles cited by publishing and non-publishing firms should shrink over time.

Table 8 presents the results where we use firm-year observations with at least one patent citation to science. This leaves us with 850 firms and 6,251 observations. Our dependent variable is the average publication year of cited articles. As before, we remove publications in trade journals and conference proceedings and non-leading journals by field. Our results are remarkably insensitive to whether we use industry fixed effects (columns 1 and 2) or firm fixed effects (columns 3 and 4), and they are very similar across major technology fields (columns 5–8).

The first point to note is that the coefficient of the time trend ranges between 0.97 and 1.02, and it is statistically indistinguishable from 1. In plain words, patents that are a year younger cite papers that are on average published one year later than papers cited by one year older patents. The vintage of science used in innovation, as measured by the relative average age of the scientific literature cited by patents, has remained unchanged.

Second, the coefficient of the log of publications ranges from about 0.22 to 0.35. Thus, a doubling of publication stock is associated with a reduction of about three months (column 1) to four months (column 3) in the average age of the cited scientific publications.[10] This suggests that scientific capability is important in enabling firms to absorb more recent scientific knowledge, although of course it is also likely that firms that publish also work on more cutting-edge innovation.

Finally, there is very little evidence to suggest that investments in science have become less effective over time in helping firms absorb external science. Columns 2 and 4 include an interaction between the stock of publications and a time trend. The coefficient of the time trend is small and insignificant. It is similarly small and insignificant when we look across technology domains, with the exception of chemicals.[11] To sum up, we find no evidence that science has become less relevant for innovation, or that the relevant scientific knowledge is of older vintage. We also find no evidence that internal scientific capability is becoming less effective in helping firms absorb scientific knowledge.

[10] For instance, from column 1, a doubling of publication stock implies that the average publication year of the cited publication increases by 0.22, which is equivalent to reducing the average age by nearly three months.

[11] Of course, there are additional dimensions other than quick absorption of external knowledge that absorptive capacity may affect. For example, absorptive capacity may allow firms to identify relevant knowledge that is geographically distant from the firm, or assess the quality of this knowledge, or how close it is from a technical standpoint to the firm core knowledge. It would be interesting to examine these additional dimensions in future work.

6.2. American regulatory changes

Changes in the U.S. regulatory environment such as the Sarbanes-Oxley Act of 2002 and the Bayh–Dole Act of 1980 are said to have discouraged large American firms from making longer-term investments, including investments in scientific capability. To test the conjecture that our results are driven by American regulatory changes, we expand our data to European firms. We match publication and patent records to all European firms from Amadeus (private and public firms). We identify about 58,000 publications by 3,642 firms, and 210,000 patents by 10,053 firms. Lacking data on R&D expenditures for European firms, we restrict attention to firms that either patent or publish at least once during the sample period of 1997–2007, the period for which financial data are available. Of these firms, about 31 percent publish at least once, and the vast majority, over 90 percent, patent at least once between 1997 and 2007.

Table 9 presents the estimation results for within-firm changes in number of publications and patents. We observe a very similar pattern of results for the European firm sample. Publications decline over time (column 1), even after we control for firm sales, which are only available a sub-sample of firms for 1997–2007 (column 2). Publications decline at about the same rate for private as for public firms (column 3), which rules out the short-termism that is sometimes attributed to public equity markets as a reason. The rate of decline is similar when we restrict attention to firms that are present in the sample for longer than 10 years (column 4), and even greater when we focus only on firms that started to invest in science prior to 1980 (column 5). Finding that European firms display similar reductions in investment in science as American firms is not consistent with the idea that specific regulatory changes in American institutions drive the results of this paper.

[Insert Table 9 here]

6.3. Globalization

Another possible explanation for why large firms have reduced their investments in scientific capability is increased competition from overseas, particularly from low-wage countries. To explore this mechanism, we follow Bloom et al. (2011) and calculate the level of Chinese import penetration as the share of the value of imports originating from China in the total imports in an industry from 1998 to 2008.[12] For each industry we compute the change in Chinese import penetration from 1998

[12] The import data is from the UN Comtrade database that tracks annual bilateral import and export trade volumes between pairs of countries. We aggregate the trade value between China to industry four-digit SIC level from the six-digit product level, and normalize the Chinese imports by domestic production figures from Eurostat's Prodcom database. Please see Bloom, Draca, and Van Reenen (2011) for more details.

to 2008. We observe a significant rise in imports from China over time across industries: import rates more than double, from an average of 2 percent in 1998 to 5 percent in 2008. We use changes in Chinese import penetration as our measure of increased globalization.

Columns 1–2 of Table 10 show a strong negative relationship between increased imports from China and the number of publications. The dependent variable is the three-year change in publications, and the regressors are also computed as three-year changes, with the obvious exception of the time trend. The standard errors are adjusted to allow for the serial correlation and are clustered at the firm level. Controlling for changes in Chinese import penetration explains the within firm decline in publications over time. Not controlling for Chinese imports (column 1), the coefficient estimate on time trend is negative and statistically significant from zero (-0.011 with a standard error of 0.005). Yet, controlling for Chinese imports (column 2), the coefficient estimate of the time trend in publication is small and insignificantly different from zero.

Columns 3–5 presents the results for the relationship between three-year changes in Chinese import penetration and corresponding changes in patent output, R&D expenditures, and physical investment. As with publications, we find a negative relationship for R&D and physical investment. It appears that increases in import competition from low-wage countries (proxied here by imports from China) tend to reduce forward-looking investments in both tangible and intangible capital. Interestingly, however, and consistent with Bloom et al. (2011), the propensity of our firms to patent appears to increase in sectors that experience an influx of Chinese imports over time.

Table 11 presents the estimation results for stock market value. Column 1 includes interactions terms between changes in Chinese import penetration and publication and patent stocks. We find that the stock market value of publications declines with an increase in Chinese imports, but the value of patent stock does not. Columns 2 and 3 report results for industries which experienced a sharp rise in Chinese import penetration and those that experienced only a modest increase in Chinese imports. As shown in Column 2, the decline in the value of publications and the increase in the value of patents over time are strongly evident in the industries facing high competition from China, but not in those insulated from Chinese imports (column 3). For industries insulated from Chinese imports, the value of publications and patents remains stable over time.

Overall, therefore, our evidence suggests that growing globalization is a plausible mechanism for why large firms in advanced economies are withdrawing from science. Firms in sectors that experience a large increase in Chinese import penetration also appear to disproportionately reduce their investments in science, R&D expenditures, and physical investment, while increasing their propensity to patent. The stock market value of publications also declines with an increase in Chinese imports, while the value of patent stock tends to increase.

It is important to stress that, as with other analyses, we are measuring association rather than causal structure. For instance, it is possible that industries where opportunities for radical innovation—innovation drawing upon scientific knowledge—are declining are also those which face greater import competition from China. Our objective here is not to provide definitive results but to see whether the data provide prima facie support for some mechanisms relative to others. We also emphasize that the decline in the value that large firms attach to scientific capability predates 2001, the year China entered the WTO. Thus, China should be seen as an instantiation of a broader trend, not fully captured in our empirical analysis, wherein the growth of competition from lower-wage countries is pushing firms away from science and toward more applied research.

[**Insert Tables 10–11 here**]

6.4. Firm scope

Large firms may also be withdrawing from science because they are pursuing more focused strategies. We use firm-level data on sales concentration from the Compustat line of business database to test the idea that firms with an increasingly narrower product base are most likely to reduce their investments in science. Between 1980 and 2007, after controlling for the increase in size of firms, there is very little decrease in the scope of firms. Based on a regression of Herfindal-Hirschman Index (HHI) of sales concentration by industry segments on a time trend, sales, and industry fixed effects, we estimate that over the sample period, the HHI of the average firm increased by about 6.5% of the initial value, or less than 0.2% per year. This masks considerable variation across firms in firm scope. We therefore examine the relationship between changes in firm scope, as measured by how concentrated the firm's sales are across industry segments, to its publication output.

The results of Table 12 are effectively within-firm estimates, relating changes research to changes in the firm's scope. The dependent variable in Column 1 is the three-year change in the output of scientific publications, and the key independent variables are also computed as three-year changes. As before, the standard errors are robust to serial correlation and clustered at the firm level. We see that there is a strong negative relationship between changes in firms scope and publications, controlling for size and changes in the R&D stock. Based on the estimates from column 1, we find that moving from the lowest to the highest decile of decreases in firm scope is associated with a drop of 87 percent of sample average decline in publications. However, as columns 2 and 3 show, the decline in patents and R&D investment is much smaller and we cannot reject the null hypothesis of no decline.

Columns 4–5 examine whether the decline in the stock market value of publications is more pronounced in the subsample of firms that have become more focused over time. Column 4 shows that for firms which have narrowed their scope, the implied stock market value of publications declines over time. By contrast, as Column 5 shows, for firms whose scope has widened, there is no such decline. Also consistent with the general trends reported earlier, the implied stock market value of patents increases rather than decreases, for both types of firms. Moreover, the implied value of patent for firms with narrowing scope grows at least as fast as that of firms whose scope has not narrowed over time. Overall, our results are consistent with the conjecture that investments in science benefits mostly diversified firms. Firms that have narrowed their scope derive less value from scientific capability and have accordingly reduced their investments in science.

[**Insert Table 12 here**]

7. Discussion

The discourse among managers and strategy consultants often centers on how firms can grow. Innovation features prominently in such discussions. Innovation has many sources but in the ultimate analysis, without advances in the stock of scientific knowledge, technical progress will eventually falter, as will the rate of innovation. Of course, firms have drawn upon the stock of public scientific knowledge to fuel their innovation efforts, but they also invested in developing and maintaining internal scientific capability as well. In so doing, they hoped for new goods and services to emerge from research labs, but also banked on in-house scientists to guide technical search, acquire relevant external technology, and serve as talent magnets. They did so understanding that investments in internal scientific capability would not pay off right away but would take time to materialize. Only firms willing to take the long view would invest in internal science.

Our results highlight two key, possibly interrelated factors that in recent times may have induced large firms to adopt more short-term strategies and reduce their investments in science.

One factor is narrower firm scope. At least since the 1990s, many firms have been focusing on their "core competencies," possibly as the result of growing competition. While concentrating on a narrower set of products or a smaller portion of the value chain can have advantages, basic research (and its unpredictable fruits) may be less valuable to these firms. This can in principle explain both a reduction in investment in science by less diversified firms, and a lower implied value for basic research investment.

Another factor that may have induced firms to withdraw from science is globalization. Globalization and increased competition may reduce the payoff to innovation, reducing the value of scientific capability. Competition from low-cost countries can also depress private investments in science by reducing cash flows, thereby reducing the amount of internal funds available to fund research. This second financial constraints argument can explain why firms invest less in science, but is hard to reconcile with a decline in the market value premium for scientific capability. If firms that invest in scientific capability are the ones that are able to overcome financial constraints, then the market should respond positively to such investments, not negatively. One possibility is that markets, as well as managers, become more short-term oriented when firm profitability declines (as a result of global competition). Alternatively, it could be that investment in internal science is an inefficient relic of a past long gone, when big American and European firms could afford to "waste" resources. In this view, large firms are inefficient performers of research and need to be pushed to outsource research to smaller and more nimble partners.

We find little support for other potential explanations for our results. One is that large firms have merely changed their publication practices rather than reduce their investment in science. A decline in publication output may reflect not changes in R&D composition, but rather a rejection of "open science" in favor of greater focus on patents or secrecy.[13] Were this so, we would expect large firms to reduce publications in applied scientific journals, which contain findings more likely to be commercially relevant. We find instead that the decline in firm publications is most prominent for publications in high-impact scientific journals, as well as in journals dedicated to basic rather than applied research. Furthermore, if changes in publication were simply due to changes in disclosure strategy but firms continued to value scientific capability to the same extent, we would not expect to find any reduction in the premium firms pay to acquire scientific capability through M&A. Instead, we find that the premium for the scientific capability of firms acquired in M&A has declined. This suggests that the decline in publications and the increase in patenting are not merely driven by a change in publication strategy. Rather, large firms appear to be moving away from basic and scientific research and toward more applied and incremental research.

[13] On conceptual grounds, Gans et al. (2013) argue that patenting and publishing are complements rather than substitutes. Complementarities between patenting and publishing exist to a large extent due to the dual disclosure strategies of inscribing the same piece of knowledge both in a patent and in a publication (Murray, 2002; Fabrizio and Di Minin, 2008). Because of this complementarity, stronger patent protection ought to increase rather than decrease publication. However, scientists with limited time may allocate more time to patents and less to publications if firms are increasing the rewards for patents as compared to publications. This would make patenting and publishing substitutes rather than complements (Bhaskarabhatla and Hegde, 2014).

Other mechanisms for which we find little support in our data include a reduction in the relevance of science for innovation, a diminished importance of absorptive capacity, and changes in U.S. regulatory environment. One, admittedly imperfect, way of tracing the application of science to technology is to use the citations patents make to scientific publications. We show that scientific knowledge continues to be relevant for innovation (i.e., patents continue to cite science) and that *new* science in particular remains important (i.e., the vintage of scientific knowledge used in innovation has not changed over time). Thus, our findings suggest that the withdrawal of firms from science is likely to leave an important gap in the relevant scientific base for innovation.

Using patent citations to scientific publications we also show that firms with higher scientific capability are able to draw upon more recent scientific knowledge in their innovations, and that the relatively higher absorptive capacity they so enjoy has not eroded over time. This suggests that the reduction in investments in science is unlikely to be because scientific capability is now less helpful in enabling firms to use external knowledge. Finally, using data on European firms, we show that American regulatory changes are unlikely to drive our results. Needless to say, all these tests have limitations (for instance, absorptive capacity could confer other advantages to firms rather than simply facilitating access to more recent scientific knowledge) and further exploring potential causal mechanisms remains an important avenue for future research.

8. Concluding Remarks

Our results indicate that the willingness of large firms to invest in scientific capability has declined. This is reflected in their behavior (e.g., their propensity to publish), the acquisition price of the science-intensive firms they acquire, and the stock market premium that investors attach to scientific capability of the firms. It is also consistent with other evidence reported in the literature on the increase in alliances and licensing, as well as qualitative evidence on the decline in corporate research.

A pessimistic interpretation of these results is that private research is in decline. Established companies can no longer emulate firms such as DuPont, AT&T, or Merck, whose investments in research in the past have significantly advanced the frontiers of human knowledge. Unless public funding can make up the deficit, technical progress will slacken and eventually reduce productivity growth. Managers in established firms, struggling to satisfy increasingly assertive investors, may be disinclined to make long-term risky bets on internal science. They may look to other means to achieve their growth targets, including international expansion and sourcing inventions and knowledge from outside the firm.

The last option, external sourcing of innovation, points to a less alarming interpretation. It may well be that other organizations—smaller firms and universities—are making up the shortfall in investment in research. According to this interpretation, what is happening is a reallocation of research from large corporate labs to more efficient organizations. To the extent that public support for research falls, external sourcing may be a less viable option because the aggregate production of knowledge falls.

Admittedly, the enhanced efficiency of how research is performed can substantially offset the shortfall in the quantum of investment in research. Even so, scientific entrepreneurs need to heed these trends. Acquisition is a common exit for start-ups. If acquirers will not pay for scientific research, as our results show, it implies that start-ups will have to invest longer, until such time as the research bears fruit and the resulting innovations can be converted into patents and products. Not all organizations that are good at research are also good at converting their research into commercially relevant forms. Requiring all research-intensive start-ups to move downstream will undoubtedly be inefficient. More importantly, it would dissuade some start-ups from investing in research, reducing the overall investment into an activity that is believed to have high social returns.

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TABLE 1. SUMMARY STATISTICS FOR MAIN VARIABLES

VARIABLES	No. Obs.	Mean	Std. Dev.	Distribution 10th	50th	90th
Panel A: Compustat firms						
Market value ($, mm)	11,304	5,920	20,278	33	677	12,208
Assets $_{t-1}$ ($, mm)	11,304	3,017	9,681	24	397	7,328
Sales $_{t-1}$ ($, mm)	11,304	3,410	9,805	35	677	12,208
Publication stock	11,304	58	389	0	0	20
Publication flow	11,304	10	58	0	0	8
Patent stock	11,304	174	664	2	19	314
Patent flow	11,304	26	101	0	2	46
Panel B: Acquisition target firms (SDC Platinum)						
Target value ($, mm)	26,884	155	251	6	57	424
Net assets ($, mm)	26,884	75	116	2	30	209
Sales ($, mm)	26,884	133	51	4	51	400
Publication stock	836	3	13	0	0.2	6
Patent stock	3,767	31	73	0	4	87

Notes: This table presents summary statistics for the main variable used in the estimation for our sample of Compustat and SDC firms. Panel A includes R&D-performing Compustat firms, and Panel B includes all target firms from SDC Platinum in the period 1985–2007 with deal value and assets information.

TABLE 2a. RESEARCH AND THE STOCK MARKET VALUE OF R&D-PERFORMING FIRMS

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Pubs /R&D	Patents/ R&D	R&D/ Sales	ln(*Market value*)		
VARIABLES					1980–1997	1998–2007
Time trend	-0.042**	-0.037**	0.004	0.091*		
	(0.006)	(0.006)	(0.006)	(0.046)		
Time trend ×ln(*Publication Stock*)$_{t-1}$				-0.002**		
				(0.0008)		
Time trend × ln(*Patent Stock*)$_{t-1}$				0.004**		
				(0.001)		
ln(*Publication Stock*)$_{t-1}$				0.074**	0.066**	0.024
				(0.014)	(0.024)	(0.027)
p-value for difference in estimates:					*p-value* <0.01	
ln(*Patent Stock*)$_{t-1}$				0.066**	0.095**	0.153**
				(0.014)	(0.023)	(0.023)
Dummy for Research Lab					0.217*	0.058
					(0.091)	(0.076)
p-value for difference in estimates:					*p-value* <0.01	
ln(*Assets*)$_{t-1}$				0.306**	0.266**	0.372**
				(0.017)	(0.026)	(0.038)
ln(*R&D Stock*)$_{t-1}$				0.066**	0.049**	0.076**
				(0.014)	(0.018)	(0.015)
ln(*Sales*)$_{t-1}$	-0.403**	-0.229**	-0.167**	0.488**	0.522**	0.422**
	(0.049)	(0.049)	(0.045)	(0.019)	(0.033)	(0.042)
Firm fixed effects	Yes	Yes	Yes	No	No	No
Industry dummies	-	-	-	Yes	Yes	Yes
R^2	0.918	0.852	0.845	0.842	0.853	0.818
Observations	11,304	11,304	11,304	11,304	5,288	6,016

Notes: This table presents estimation results for investments in research by publicly listed R&D-performing American firms for the period 1980–2007. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

TABLE 2b. PUBLICATIONS AS A MEASURE OF INVESTMENT IN SCIENTIFIC RESEARCH

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Flow of scientific publications		Share basic	ln(Market value)	
Publications:	Basic	Applied	All	All	All
Time trend	-0.005**	-0.001	-0.023**	0.086*	0.115
	(0.002)	(0.003)	(0.008)	(0.046)	(0.072)
Time × ln(*Basic publication stock* $)_{t-1}$				-0.019*	
				(0.001)	
Time × ln(*Applied publication stock* $)_{t-1}$				0.001	
				(0.001)	
Time × ln(*Share basic publication stock* $)_{t-1}$					-0.003**
					(0.001)
Time trend × (P*ublication stock* $)_{t-1}$					-0.001
					(0.001)
ln(1+*Basic publication stock* $)_{t-1}$				0.071**	
				(0.014)	
ln(1+*Applied publication stock* $)_{t-1}$				-0.024	
				(0.015)	
ln(1+*Publication stock* $)_{t-1}$					0.047**
					(0.013)
ln(*Share basic publication stock* $)_{t-1}$					0.051**
					(0.019)
Time trend × ln(*Patent stock* $)_{t-1}$				0.005**	0.003**
				(0.001)	(0.001)
ln(1+*Patent stock* $)_{t-1}$				0.064**	0.063**
				(0.013)	(0.017)
ln(*R&D stock* $)_{t-1}$	0.013**	0.034**	-0.214**	0.071**	0.033**
	(0.006)	(0.011)	(0.055)	(0.005)	(0.007)
ln(*Sales* $)_{t-1}$	0.015	0.032**	0.117**	0.489**	0.669**
	(0.009)	(0.013)	(0.067)	(0.019)	(0.028)
ln(*Assets*)				0.308**	0.219**
				(0.017)	(0.026)
Two-digit industry dummies	Yes	Yes	Yes	Yes	Yes
Country target dummies	Yes	Yes	Yes	Yes	Yes
Acquisition year dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.944	0.871	0.935	0.853	0.891
Observations	11,304	11,304	4,955	11,304	4,955

Notes: This table presents estimation results when we distinguish between basic and applied scientific publications as indicated by the CHI journal database. Publications are classified as basic if they are published in journals with a CHI level of 4, and as applied if they are published in journals with a CHI level of 1. Columns 3 and 5 include only publishing firms. Publications and patents are always weighed by citations. Standard errors (in brackets) are robust to arbitrary heteroskedasticity. * significant at 5%; ** significant at 1%.

TABLE 3. INVESTMENT IN RESEARCH BY INDUSTRY OVER TIME

	(1)	(2)	(3)
Dependent variable:	Publications /R&D	Patents/ R&D	R&D/ Sales
Time trend	-0.037**	-0.049**	-0.001
	(0.003)	(0.003)	(0.003)
Time trend ×:			
Dummy for Biotechnology	0.016**	-0.020**	0.028**
	(0.005)	(0.006)	(0.006)
Dummy for Chemicals	0.015**	0.004	-0.002
	(0.004)	(0.004)	(0.004)
Dummy for Pharmaceuticals	-0.021**	-0.010	-0.004
	(0.005)	(0.007)	(0.006)
Dummy for Electronics	-0.005	0.019**	-0.007
	(0.004)	(0.005)	(0.004)
Dummy for IT	-0.011**	0.002	-0.001
	(0.004)	(0.005)	(0.004)
Dummy for Semiconductors	-0.024**	-0.005	0.013**
	(0.004)	(0.005)	(0.004)
Dummy for Telecommunications	0.007	0.029**	0.013**
	(0.005)	(0.005)	(0.004)
Firm fixed effects	Yes	Yes	Yes
R^2	0.919	0.854	0.845
Observations	11,304	11,304	11,304

Notes: This table examines time trends in research across industries. Firms are classified into industries based on the distribution of their patents by technology areas. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

TABLE 4. RESEARCH AND STOCK MARKET VALUE BY INDUSTRY OVER TIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	ln(*Market value*)						
Variables	Biotech	Chemi-cals	Pharma	Elect-ronics	IT	Semicon-ductors	Telecom
Time trend × ln(*Publication Stock*)$_{t-1}$	-0.001	-0.002*	-0.003*	-0.003**	-0.003**	-0.003*	-0.005**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Time trend × ln(*Patent stock*)$_{t-1}$	0.005**	0.004**	0.007**	0.006**	0.007**	0.004*	0.009**
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
ln(*Publication stock*)$_{t-1}$	0.134**	0.154**	0.139**	0.114**	0.157**	0.068**	0.136**
	(0.021)	(0.017)	(0.022)	(0.016)	(0.018)	(0.022)	(0.020)
ln(*Patent stock*)$_{t-1}$	-0.035	-0.002	-0.086**	0.034	-0.038	0.148**	-0.065*
	(0.027)	(0.024)	(0.029)	(0.021)	(0.025)	(0.036)	(0.031)
Time trend	-0.009	0.012	0.005	0.024*	0.020*	0.034**	0.013
	(0.013)	(0.009)	(0.015)	(0.008)	(0.009)	(0.012)	(0.011)
ln(*Assets*)$_{t-1}$	0.315**	0.453**	0.320**	0.349**	0.310**	0.274**	0.228**
	(0.041)	(0.028)	(0.041)	(0.023)	(0.026)	(0.034)	(0.031)
ln(*R&D stock*)$_{t-1}$	0.021	0.053**	0.070	0.012	0.007	0.063**	-0.006
	(0.016)	(0.012)	(0.018)	(0.007)	(0.009)	(0.017)	(0.011)
ln(*Sales*)$_{t-1}$	0.418**	0.323**	0.390**	0.543**	0.579**	0.505**	0.677**
	(0.042)	(0.030)	(0.037)	(0.026)	(0.029)	(0.035)	(0.034)
R^2	0.846	0.828	0.833	0.836	0.816	0.851	0.836
Observations	1,465	3,025	1,604	4,590	3,391	2,013	2,064

Notes: This table examines time trends in the stock market value of research across industries. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

TABLE 5. RESEARCH AND TARGET'S FIRM VALUE OVER TIME

Dependent variable: ln(*Target's firm value*)	(1)	(2)	(3)	(4)	(5)
	All Years	1985-1997	1998-2007	Innovating targets	Excluding IT
Time trend × ln(*Publication stock*)$_{t-1}$	-0.018**			-0.017**	-0.019**
	(0.005)			(0.005)	(0.005)
Time trend × ln(*Patent stock*)$_{t-1}$	0.003**			0.002	0.003**
	(0.001)			(0.001)	(0.001)
ln(1+*Publication stock*)$_{t-1}$	0.292**	0.169**	-0.043	0.266**	0.314**
	(0.064)	(0.040)	(0.069)	(0.062)	(0.065)
p-value for difference in estimates:		*p-value* <0.01			
ln(1+*Patent stock*)$_{t-1}$	0.039**	0.069**	0.072**	0.033*	0.041**
	(0.012)	(0.008)	(0.011)	(0.015)	(0.012)
ln(*Assets*)	0.592**	0.586**	0.595**	0.649**	0.598**
	(0.007)	(0.010)	(0.010)	(0.019)	(0.007)
ln(*Sales*)	0.167**	0.177**	0.157**	0.077**	0.168**
	(0.007)	(0.009)	(0.010)	(0.016)	(0.007)
Time trend	0.018**			0.011*	0.019**
	(0.003)			(0.005)	(0.003)
Two-digit industry dummies	Yes	Yes	Yes	Yes	Yes
Country target dummies	Yes	Yes	Yes	Yes	Yes
Acquisition year dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.654	0.678	0.633	0.646	0.661
Observations	26,884	14,990	11,894	4,684	25,004

stocks. The sample includes all SDC Platinum deals with non-missing information on target firm value, assets and sales. The sample period is 1985–2007. Column 4 includes only target firms with at least one patent or scientific publication. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

TABLE 6. RESEARCH BY TARGET FIRMS IN THREE-YEAR WINDOW AROUND ACQUISITION YEAR

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	Flow of scientific publications						Flow of patents		
	Count			Weighed by citations			Count		
Acquisition year:	All	1985-1996	1997-2004	1985-2004	1985-1996	1997-2004	All	1985-1996	1997-2004
Post-acquisition dummy	-0.079**	0.013	-0.198**	-0.298	0.902**	-1.839**	1.171**	2.036**	0.184
	(0.023)	(0.025)	(0.041)	(0.200)	(0.248)	(0.326)	(0.467)	(0.629)	(0.698)
p-value for difference in estimates:		*p-value* <0.01			*p-value* <0.01			*p-value* <0.01	
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean dependent variable	0.57	0.57	0.58	6.1	5.6	6.7	8.6	6.6	10.3
R^2	0.865	0.901	0.819	0.614	0.640	0.590	0.953	0.911	0.97
Observations	19,475	10,615	8,860	19,475	10,615	8,860	22,369	11,040	11,329

Notes: This table reports the results of OLS regressions that examine the effect of being acquired on publishing and patenting activity. Post-acquisition dummy receives the value of one for observations where the year is later than the acquisition value and zero otherwise. We include observations in a three-year window from the acquisition year. Robust standard errors are in brackets. * significant at 5%; ** significant at 1%.

TABLE 7. USE OF SCIENCE IN INNOVATION: CITATIONS BY PATENTS TO SCIENTIFIC PUBLICATIONS

Dependent variable: *Number of patent citations to science*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	All	Publishing firms	Non-publishing firms	Pharma and Biotech	Chemicals	Electronics	Telecom and IT
Time trend	0.001	0.021	-0.017	0.045	0.016	0.046**	-0.001
	(0.015)	(0.017)	(0.020)	(0.055)	(0.040)	(0.014)	(0.014)
Cites made	0.089**	0.089**	0.089**	0.122**	0.100**	0.079**	0.133**
	(0.011)	(0.015)	(0.013)	(0.044)	(0.029)	(0.012)	(0.017)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.582	0.497	0.596	0.621	0.637	0.485	0.526
Observations	11,304	4,411	6,893	2,138	3,275	5,023	4,041

Notes: This table examines time trends in citations to scientific articles by patents for our Compustat sample of R&D-performing firms. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

TABLE 8. USE OF SCIENCE IN INNOVATION: AVERAGE AGE OF SCIENCE CITED IN PATENTS

	Dependent variable: *Average publication year of cited science*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	Within-industries	Within-industries	Within-firms	Within-firms	Pharma and Biotech	Chemicals	Electronics	Telecom and IT
Time trend	0.974**	0.977**	1.001**	1.007**	0.983**	1.065**	0.978**	1.019**
	(0.012)	(0.015)	(0.018)	(0.024)	(0.036)	(0.030)	(0.031)	(0.033)
ln(*Patent stock*)$_{t-1}$	-0.122*	0.123*	0.012	0.011	0.278	0.016	0.216	0.201
ln(*Publication stock*)$_{t-1}$	0.224**	0.254**	0.317*	0.353*	0.249	0.286	0.219	0.265
	(0.036)	(0.071)	(0.158)	(0.191)	(0.208)	(0.195)	(0.198)	(0.191)
Time trend × ln(*Publication stock*)$_{t-1}$		-0.002		-0.002	0.002	-0.013**	0.001	-0.004
		(0.004)		(0.005)	(0.006)	(0.005)	(0.005)	(0.005)
	(0.063)	(0.063)	(0.107)	(0.107)	(0.209)	(0.155)	(0.132)	(0.146)
ln(*Sales*)$_{t-1}$	-0.058	-0.058	-0.668**	-0.672**	-0.548**	-0.533**	-0.439*	-0.655**
	(0.055)	(0.055)	(0.131)	(0.132)	(0.172)	(0.163)	(0.213)	(0.210)
Industry fixed effects	Yes	Yes	-	-	-	-	-	-
Firm fixed effects	No	No	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.580	0.580	0.691	0.691	0.786	0.735	0.714	0.736
Observations	6,251	6,251	6,251	6,251	1,789	2,529	3,418	3,041

Notes: This table examines the relationship between average publication year of cited articles and a firm's publication stock. The estimation sample consists of firms with patents that cite scientific articles. Standard errors (in brackets) are robust to arbitrary heteroskedasticity. * significant at 5%; ** significant at 1%.

TABLE 9. INVESTMENT IN SCIENCE BY EUROPEAN FIRMS

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	*Flow of scientific publications*				
	All	Non-missing sales	Public *vs.* private	Sample years >10	First pub< 1980
Time trend	-0.046**	-0.111**	-0.045**	-0.066**	-0.212**
	(0.011)	(0.030)	(0.011)	(0.015)	(0.050)
ln(*Sales*)		0.322**			
		(0.137)			
Time trend × *Dummy for public*			-0.012		
			(0.024)		
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.724	0.676	0.724	0.722	0.719
Observations	38,018	15,135	38,018	11,451	2,999

Notes: This table examines time trends in scientific publications by European firms. We match our publication dataset to all Amadeus (private and public) firms. Financial data is available only from 1997, not for all firms. R&D is never reported. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. *

TABLE 10. GLOBALIZATION AND INVESTMENT IN RESEARCH, 1998-2007

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	ΔPubs		ΔPats	ΔR&D	ΔCapx
ΔChinese import penetration		-1.725**	2.635**	-0.431*	-1.989**
		(0.563)	(0.716)	(0.244)	(0.403)
Time trend	-0.011**	0.001	-0.063**	-0.010**	0.003
	(0.005)	(0.007)	(0.009)	(0.003)	(0.005)
Δ*R&D stock*	0.042*	0.038*	0.397**		
	(0.019)	(0.019)	(0.055)		
Δ*Sales*				0.474**	0.854**
				(0.031)	(0.053)
R^2	0.002	0.005	0.038	0.260	0.337
Observations	4,354	4,354	4,354	4,354	4,354

Notes: This table presents the estimation results for the effects of Chinese import penetration on investment by Compustat firms. Changes in Chinese import penetration are computed as the three-year change in import penetration. Changes in R&D stock and sales are similarly calculated as 3 year changes. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. *

TABLE 11. GLOBALIZATION AND MARKET VALUE

Dependent variable: ln(*Market value*)

	(1)	(2)	(3)
		Chinese import	
		High (75^{th} pct.)	Low (25^{th} pct.)
ΔChinese import penetration × ln(*Publication stock*)$_{t-1}$	-0.803**		
	(0.330)		
ΔChinese import penetration × ln(*Patent stock*)$_{t-1}$	-0.018		
	(0.323)		
Time trend × ln(*Publication stock*)$_{t-1}$		-0.010**	0.001
		(0.003)	(0.001)
Time trend × ln(*Patent stock*)$_{t-1}$		0.010**	0.001
		(0.002)	(0.002)
ln(*Publication stock*)$_{t-1}$	0.084**	0.065	0.086**
	(0.015)	(0.042)	(0.022)
ln(*Patent stock*)$_{t-1}$	0.153**	0.031	0.068**
	(0.016)	(0.033)	(0.028)
ln(*Assets*)$_{t-1}$	0.436**	0.337**	0.288**
	(0.037)	(0.055)	(0.032)
ln(*R&D stock*)$_{t-1}$	0.096**	0.065**	0.154**
	(0.010)	(0.018)	(0.013)
ln(*Sales*)$_{t-1}$	0.339**	0.579**	0.387**
	(0.039)	(0.066)	(0.033)
Time trend		0.174	0.175*
		(0.118)	(0.099)
ΔChinese import penetration	-0.372**		
	(1.290)		
R^2	0.789	0.805	0.873
Observations	3,540	1,755	2,077

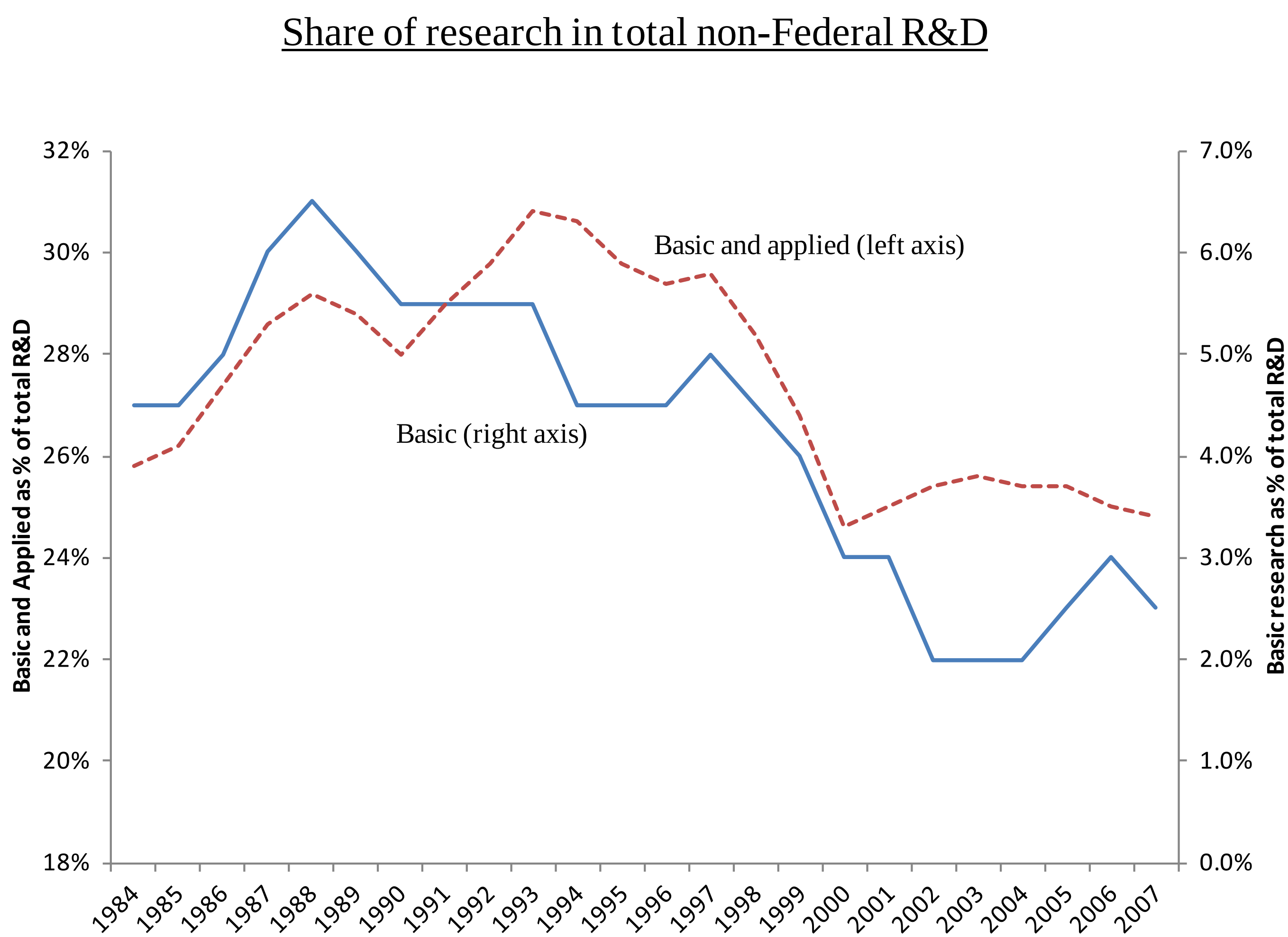
Notes: This table presents the estimation results for the effects of Chinese import penetration on the stock market value of publications. In column 1, the estimation period is 1998–2007. In columns 2 & 3, the estimation period is 1980–2007. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

TABLE 12. NARROWER FIRM SCOPE

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	ΔPubs	ΔPats	ΔR&D	ln(*Market value*)	
Dependent variable:				ΔHHI SIC>0	ΔHHI SIC≤0
ΔHHI SIC	-0.323*	-0.113	-0.060		
	(0.145)	(0.097)	(0.048)		
Time trend	-0.022	-0.006			
	(0.016)	(0.004)			
Δ*R&D stock*	0.240	0.378**			
	(0.161)	(0.062)			
ln(*Sales*)$_{t-3}$	0.107**	0.036**	0.002		
	(0.040)	(0.015)	(0.007)		
Δ*Sales*			0.391**		
			(0.039)		
Time trend × ln(*Publication stock*)$_{t-1}$				-0.004**	-0.001
				(0.001)	(0.001)
Time trend × ln(*Patent stock*)$_{t-1}$				0.006**	0.004**
				(0.001)	(0.001)
ln(*Publication stock*)$_{t-1}$				0.109**	0.051**
				(0.020)	(0.020)
ln(*Patent stock*)$_{t-1}$				0.030	0.077**
				(0.023)	(0.018)
ln(*Assets*)$_{t-1}$				0.296**	0.278**
				(0.036)	(0.023)
ln(*R&D stock*)$_{t-1}$				0.043**	0.073**
				(0.009)	(0.007)
ln(*Sales*)$_{t-1}$				0.580**	0.517**
				(0.044)	(0.026)
R^2	0.039	0.113	0.282	0.887	0.827
Observations	7,573	7,573	7,558	2,609	6,653

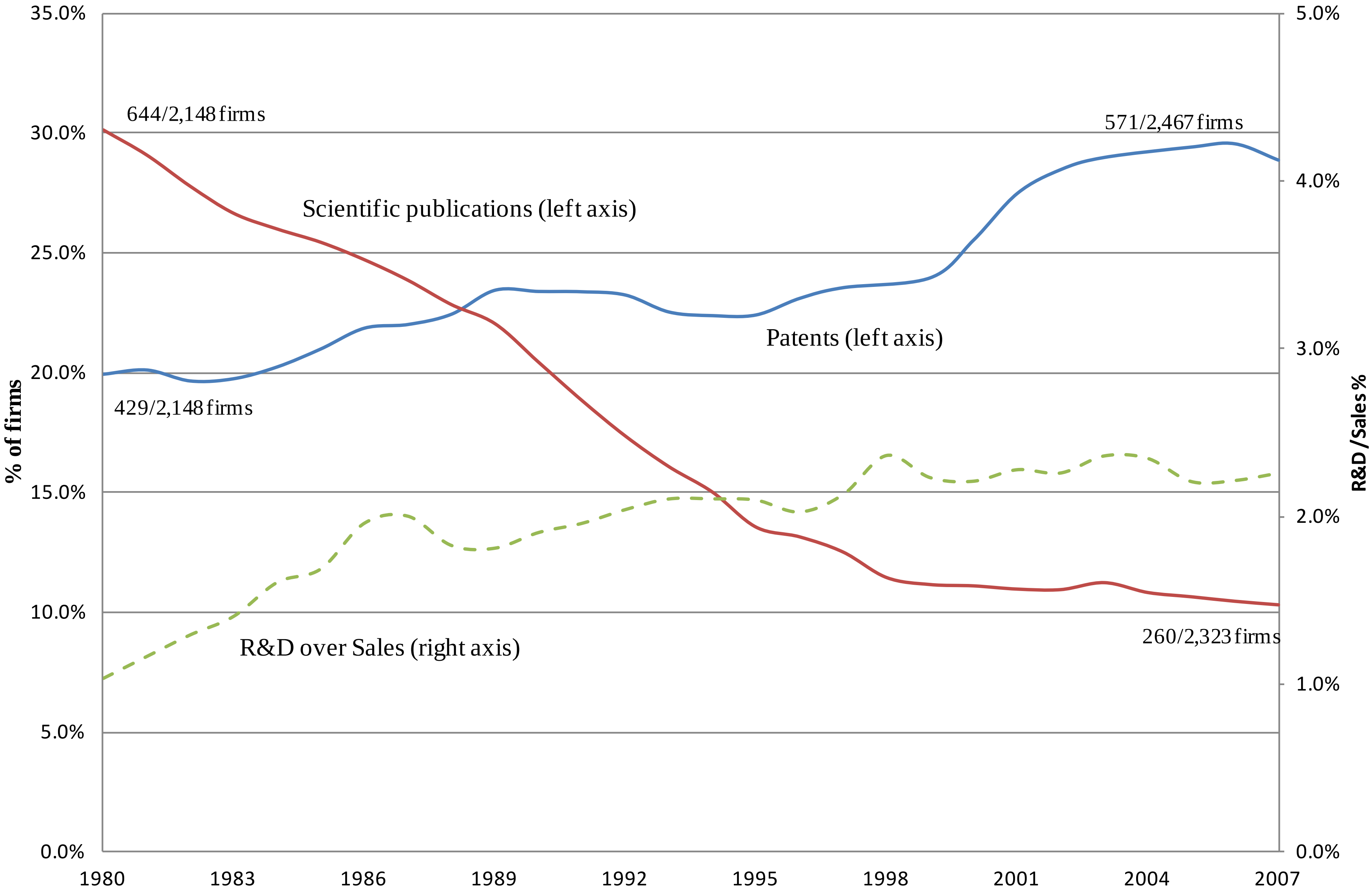
Note: This table examines the relationship between narrower firm scope and investments in research and its implied value over time. Changes are at the three-year window preceding the focal year. For instance, column 1 uses the change in the flow of publications produced in the given year minus the flow of publications produced three years prior to that. Other changes are similarly defined. HHI is based on Compustat line-of-business data. Column 4 restricts the sample to firms that have narrowed their scope, whereas column 5 restricts the sample to firms that have increased their scope. All regressions include industry dummies. Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 5%; ** significant at 1%.

Figure 1: Investment in Science and Technology Over Time, NSF Data



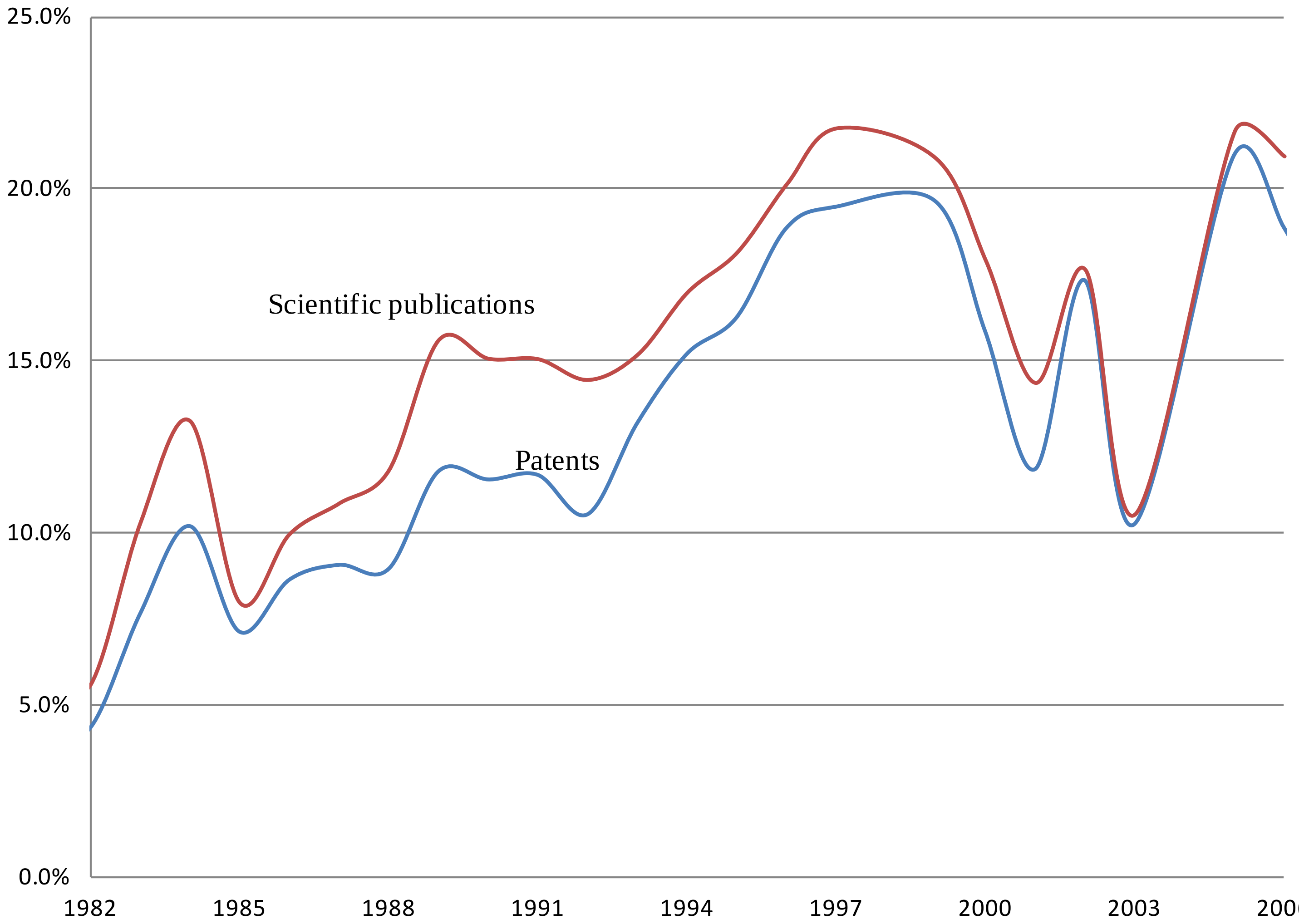
Data source: National Science Foundation/Division of Science Resources Statistics, Survey of Industrial Research and Development: 2007.

Figure 2: Investment in Science and Technology Over Time



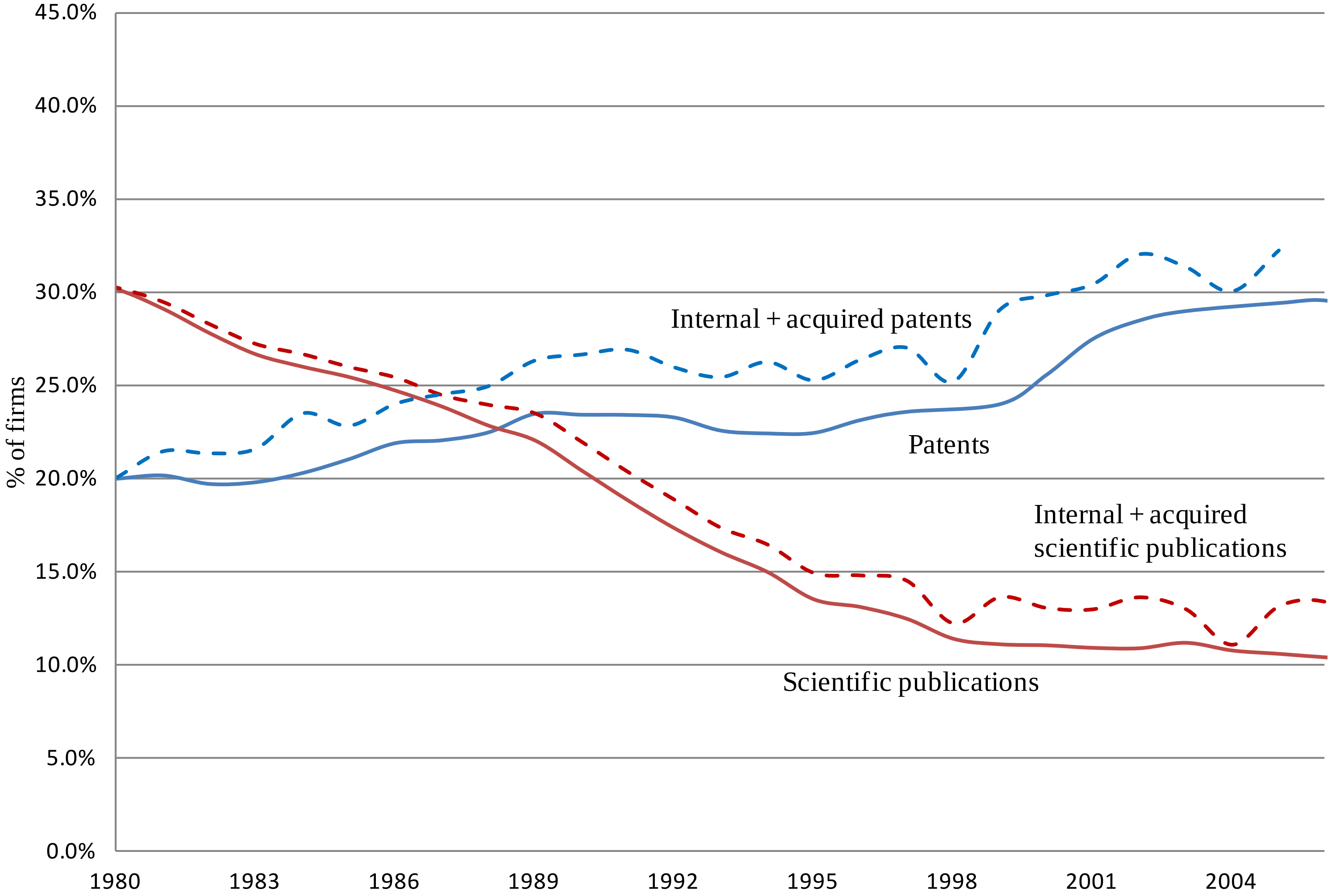
Note: This figure presents the share of publishing and patenting firms of all Compustat firms with at least one year with non-zero R&D expenditures, over time. Data source: Compustat, Web of Science, PatStat.

Figure 3: Sourcing of Science and Technology Over Time



Note: This figure presents the share of publishing firm that acquire targets with scientific publications, and the share of patenting firms that acquire targets with patents, over time (3-year moving average). The dotted line plots the share of firm scientific articles that are coauthored with an external scientist. Data source: SDC Platinum, Web of Science, PatStat.

Figure 4: Combining Investment in Science and Technology and Sourcing Over Time



Note: This figure combines internal and acquired publications and patents. The dashed lines present the combined shares.
Data source: Compustat, SDC Platinum, Web of Science, PatStat.