INSTITUTIONS AND INNOVATION: A LITERATURE REVIEW OF THE IMPACT OF PUBLIC R&D AND FINANCIAL INSTITUTIONS ON FIRM INNOVATION

"The most important thing is to have access to risk capital. Markets are in place, but you need money pools for people who just have a brilliant idea," – Eric Schmidt, CEO, Google

“Universities spin out technology companies at an ever increasing rate - but the need is for a much increased venture capital pot to get them started.” – Sir Roy Anderson, Chief Scientific Advisor, UK Ministry of Defense, Head of the Department of Infectious Disease Epidemiology at Imperial College London

“Our greatest lack is not money for any undertaking, but rather ideas. If the ideas are good, cash will somehow flow to where it is needed.” - Robert H. Schuller, author and televangelist

Introduction

Institutions and the environment matter for innovation, but which institutions matter more? How do they matter at a more micro-level? It is clear from work in institutional economics that the levels and modes of innovative and entrepreneurial activity should be affected by the surrounding institutions (Licht, Siegel 2006, Busenitz, Gomez, Spencer 2000). Institutions can help alter the constraints and structure of incentives in a society to direct self-interested behavior towards either more or less economically productive activities (Baumol 1990, Nee 1996). New opportunities open up as emerging economics undertake the shift from redistributive bureaucracy to open markets (Nee 1996), but we still lack an understanding of which shifts are more important for increasing technological innovation. The environment for entrepreneurship along with differences in technological opportunities, the characteristics of economic spillovers between universities and private firms, along with cultural factors can impact the level and types of entrepreneurial activity occurring. Yet currently we have a limited understanding of these factors. This paper focuses specifically on the impact of two broad institutions: financial and
public R&D institutions.

The question can also be thought of as whether the constraints to innovation are most binding at the relative end of the research process (funding) or the beginning (new ideas). The promise of a less aggregate level exploration of the dynamics of growth and innovation is that it may yield insights into the processes driving firm-level growth with central implications for firm strategy.1 Investigating microeconomic implications of the more aggregate models may be necessary to provide more discriminating tests since the data currently available could (and have been shown already to) fit any number of models. The literature on firm growth is closely related, but surprisingly these two strands of literature have only rarely been discussed together (Ijiri, Simon 1976, Sutton 1997).

The purpose of this paper is not to argue whether the environment or the individuals play a larger role in choosing or determining strategy, but rather to uncover the types of resources that constrain strategic choice (Hrebiniak, Joyce 1985).

**Evolutionary Theory and Search Models**

Based on an evolutionary theory of firm development, we develop hypotheses about the mechanisms through which the external environment shapes the search and selection of a firm strategy. The particular strategy that we are interested in is the choice of an innovation strategy and the research and development (R&D) activity of firms. Similar to their biological counterparts, economic natural selection and organizational genetics refer to the generation of variation in organizational “traits” and the role of the market environment in creating niches to foster variation and in selecting what firms live and die (Nelson, Winter 1982). We extend the

---

1 Others have also recognized the need to reconcile more detailed firm-level work with the highly mathematical aggregate models of technological change (Klette, Griliches 2000, Thompson 1996, Thompson 2001, Peretto 1999).
theory of variation, selection, and retention to the under-explored initial stages generating variation in firm strategies. Previous research has focused on initial conditions and on the implications of certain environments and strategic choices for survival and performance. However, the intermediate mechanisms of how initial conditions lead to the variation in strategic choice have largely been overlooked (Teece, Pisano 1994).

According to the resource-based view (RBV) of the firm, differences between firms in the resources and capabilities they have gathered through superior information or luck generate differences in firm performance (Barney 1991, Peteraf 1993, Wernerfelt 1984). Competitive advantage is sustained to the extent that competitors can be prohibited from replicating valuable resources (Rumelt 1991, Hatch, Dyer 2004, Lippman, Rumelt 1982). Yet our current understanding of the beginning stage of how those initial strategies and resource positions are developed is limited. Only recently has the field begun to develop theory about dynamic processes that allow some firms to produce more valuable combinations of resources (Teece, Pisano and Shuen, 1997). Scholars are increasingly drawing on evolutionary theory to make the resource-based view of the firm more dynamic and to give a clearer picture of how resources develop and shape strategy.

Evolutionary theory provides the conceptual framework of variation, selection and retention of higher order routines that guide search processes for strategies and resources. Building on this theoretical framework, the literature on dynamic capabilities has been guided by inertial mechanisms of local search. Yet, less is known about how variation in strategies arises and how managers actively decide which strategies to pursue and what bundles of capabilities to develop. Porter (1991) also notes the need to develop a more dynamic theory of strategy.

2 Shaver notes that ignoring the selection issues of what firms decide to perform R&D can bias results and inferences (Shaver 1998).
Moving in this direction, Zott (2003) develops a model where local search drives choices between imitation and experimentation. These choices then result in differences in the timing of implementation, learning, and costs of deployment. In this way, he links dynamic capabilities with firm performance.

Cumulative learning through local search and tacit knowledge are both key theoretical concepts for an evolutionary account of firm development and strategy. Helfat (1994) provides one test of evolutionary theory in demonstrating the empirical prediction of persistence in R&D expenditures within firms and differences in R&D across firms. She also notes the link to the RBV in the implication that persistent differences in R&D can result from both the characteristics of R&D (e.g. tacitness or cumulative learning) and from firm ties to heterogeneous assets. These differences in R&D occur and persist if the particular assets are somewhat immobile across firms and possession of the assets is path dependent. Helfat (1994) points out that several key issues in the theory need to be explored, including, “the sources of initial heterogeneity in firms R&D … and the way that initial knowledge bases change in reaction to changes in the external environment.” She goes on to note that to test this, the field needs an evolutionary model of response to the external environment, which would be a “complex undertaking.” This paper attempts to undertake part of this challenge.

Prior work has sought to advance the resource based view by delineating the types of resources that generate performance and the external environments where certain resources are more important than others. Several attempts have been made to build categorizations of resources (Barney, 1991; Grant, 1991; Miller and Shamsie, 1996). Miller and Shamsie (1996) distinguish property-based resources from knowledge-based resources and show that each was associated with greater economic returns in different economic environments.
A separate but related stream of literature has focused on the effects on firm performance and survival of the initial conditions at founding. Stinchcombe (1965) argued that founding conditions largely determine the fate of new organizations and new firms must struggle to overcome a liability of newness. Scholars in this stream have shed light on the survival impact of both the environmental conditions at founding and the characteristics of the founding team (Eisenhardt, Schoonhoven 1990, Romanelli 1989, Romanelli, Tushman 1986). This literature has mainly focused on survival and performance, and less on how initial conditions shape specific strategic choices (Carroll, Khessina 2005, Hannan, Freeman 1977, Baron, Hannan, Burton 1999, Beckman, Burton, O’Reilly 2007, Beckman, Burton 2007, Burton, Sørensen, Beckman 2002). The theoretical literature has tended to abstract away from which resources or which strategies are most important for overcoming liabilities of newness, in large part skimming over the intermediate link between the endpoints of initial conditions and firm performance. Other work by Burton and Baron (1996, 1999) offers important exceptions that we seek to build on. For instance, it has been shown that the founding team’s prior functional experiences and initial organizational functional structures predict subsequent top manager backgrounds and later functional structures (Beckman, Burton 2008). In addition, the initial incumbents in functional positions appear to imprint those positions and influence the likelihood that the subsequent holders of those positions may leave (Burton, Beckman 2007). These studies provide evidence of some mechanisms by which founders bring blueprints or models that then shape the future directions of the firm (Baron, Burton, Hannan 1999).

---

3 Rajagopalan (1993) reviews the literature on the strategy making process. Under her categorization, this paper advances the environmental and organizational aspects of the framework.

4 CEO personality has been shown to also shape strategy choice (Miller, Toulouse 1986).
Local search is a key mechanism in evolutionary theory. The search approach to technological change was pioneered by Evenson and Kislev (1976) and Nelson (1982). We discuss two different searches firms undertake in gathering resources and determining strategy – a search for ideas and a search for funding. A large literature, both in the strategy field and in economics emphasizes the importance of funding for firms attempting to engage in technical innovation. Maidique and Patch (1982) discuss how innovation requires a different level of resource commitment since innovative technology often takes a long time and considerable resources to become viable. Alternatively, imitating existing products and processes can be expected to require fewer resources and a quicker time to profitability, although perhaps a lower payoff.5

Some have argued that the discovery of opportunities is a function of the information distribution across society (Hayek 1945, Shane 2000). One must discover an opportunity before one can act on it and start a new firm. Holding all else equal, shifts in the distribution of information may result in shifts in the level and type of entrepreneurship. We conceptualize the process of formulating strategy (either for a firm seeking growth or a new firm emerging) as involving an external search for ideas and for funding sources.6 Innovation has often been characterized in theoretical work as a search process (Katila, Chen 2009, Katila, Shane 2005, Katila, Ahuja 2002) or a circulation of ideas requiring feedback and further development (Hellmann, Perotti 2007, Hellmann 2007). Yet few empirical papers have examined this early stage. Levinthal and March (1981: 313), characterize innovation as a search consisting “of sampling opportunities from the pool of technological possibilities.” The search perspective is a useful one because it focuses on attempts to solve problems in an uncertain and ambiguous world.

5 Levin et al. (1987) find that imitation costs are 50-75 percent of the cost of invention.
6 Competition also may have an impact on innovation, but is outside of the scope of this paper, but for a more detailed examination, see (Aghion, Bloom, Blundell, Griffith, Howitt 2005).
(Simon, 1957; Nelson, Winter 1982, Cyert, March 1963). The adoption of an innovation strategy can be hypothesized to be determined by the expected payoffs to that search, which is a function both of the knowledge available in the environment, but also the financial resources necessary to develop and commercialize that innovation.

Although there are many reasons to be skeptical of a simplified “linear model” of research, we do still tend to think in terms of a one or two dimensional distribution of research activity (Bush 1945, Aghion, Dewatripont, Stein 2008). So-called “basic” science can be thought of as opening up new “search distributions” for applied researchers, raising the productivity and level of applied research effort in the short run. Basic research can increase the mean of the distribution searched, change its variance or discover new distributions to search through the creation of new technologies. Applied research is a search process that exhausts the technological opportunities within a particular field. The rate of progress of basic knowledge by this model, determines the rate of technological change (Evenson, Kislev 1976, Adams 1990, Adams 1993, Kortum 1997). In a similar spirit, but more recently, science has been characterized as a map of the terrain, guiding more applied development (Fleming, Sorenson 2004).

A sizable literature anchored in organizational learning theory and problem solving perspectives has explored how firms use search to innovate (Winter 1984, Huber 1991, Almeida, Dokko, Rosenkopf 2003, March 1991). In general, the insights from this literature are described below. Despite the fact that more commercially successful searches are more distant from the current knowledge-base of the firm (Greve, 2003; Taylor, Greve 2006) most searches tend to be infrequent and close to the firm’s existing activity (Helfat 1994; Benner and Tushman, 2002; Nerkar and Paruchuri, 2005). Typically, firms with successful search strategies recombine new
knowledge with current knowledge (Tushman and O’Reilly, 1996; Katila, Ahuja 2002, March 1991, Siggelkow, Rivkin 2005). The phenomenon of search processes occurring nearer or farther from the firm’s existing knowledge-base has become known in the literature by various terms, including search depth vs. scope (Katila, 2009), exploration vs. exploration, innovation vs. refinement (Levinthal and March, 1981), and slack vs. problemistic search (Cyert and March, 1963).

However, the conventional view of innovation search is mainly firm-centric. The existing studies have greatly increased our understanding of how a firm’s search activities related to its past search behavior and the performance of more novel current search paths compared to historical searches. Nonetheless, these studies have not taken into account the external environment and the types of knowledge (or knowledge workers) likely to be available externally. The distribution of the search environment is likely to be important, yet is not clearly understood in how it constrains or enables search behavior. There is a new stream of literature that is beginning to understand how the external environment, in terms of competitors and the networks to which the firm is connected, shape firm search and innovation (Katila, Chen 2009, Katila, Shane 2005, Katila, Ahuja 2002, Fleming, Sorenson 2004, Fleming 2001, Rosenkopf, Nerkar 2001, Fleming, King, Juda 2005). These studies form an important set of exceptions to the characterization above and constitute the growing stream of literature to which the current paper seeks to contribute. The literature on search is likely to benefit from insights developed in the extensive literature at a macro-level on the effects of publicly funded R&D on private firm R&D. Similarly, as echoed by others, (David, Hall 2000, David, Hall, Toole 2000), the macro-level literature (using ideas production function approaches) stands to benefit from more micro-level, fine-grained understandings of how firms and managers have been found to conduct R&D
in their firms.

Firms seek out, recombine and manipulate knowledge within the space of current and past technological knowledge. Researchers have typically used patent citations as a record of this activity (Rosenkopf and Nerkar, 2001; Benner and Tushman, 2002; Almeida et al., 2003; Singh, 2005). Prior work has focused on the idea that there are two components to the technological knowledge space that firms search (Levinthal and March, 1981; Katila and Ahuja, 2002). If the firm has chosen an innovation strategy, then it can introduce new products by recombining pieces from its existing knowledge base, or by exploring new areas outside of its current knowledge-base (or a combination of the two).\footnote{Exploratory searches tend to result in more innovative but unreliable output; and exploitative searches tend to result in lower variance, but less innovative outcomes (March, 1991; Campbell, 1977; Levitt and March, 1988; March, 1991). Exploration and exploitation have been further characterized through empirical studies. For instance, Mezias and Glynn (1993) used simulation and Rosenkopf and Nerkar (2001) archival data to demonstrate that firms that explore are more likely to generate innovative technologies.} In this framework, changes in the external knowledge environment (induced through public R&D spending) could be expected to impact firms that are already doing innovation through either of these two search methods, but not affect those firms who have chosen not to take an innovation strategy. However, shifts in the external knowledge environment may be expected to have a greater impact on new firms still in the process of choosing whether an innovation strategy is more attractive than alternative strategic positions. This process that generates the cross-section of observed innovating firms has not been explored by the literature. If models of R&D that result in persistent levels of R&D intensity by firms are correct (such as evolutionary theory) then the effects of shifts in the knowledge environment would only be expected to come about through this dynamic effect on new firms. New firms not only search the technical knowledge space for profitable opportunities, but also could search a customer or market space, a supplier space for cheaper suppliers, or a
space of existing products that could be imitated or sold in a different geographic location. The choice to search a technical knowledge space at all for profitable opportunities is a first stage that has been unaccounted for in the existing literature.

Some individuals might be pre-disposed towards searching for strategies in technology space, either because they have lower costs to searching that space (they know where to look) or they anticipate higher payoffs to technical search (they have signals of potential promising areas to search in). While researchers have traditionally looked to patent data for evidence on search behavior, recent work shows that frequently these interactions occur through co-founding, licensing, and consulting rather than through co-publishing or citations (Murray 2002, Stuart, Ding 2005). Further work in this line shows that even when scientists themselves do not directly found firms, they make use of their networks of current and former students as well as a wider cosmopolitan network of colleagues to benefit entrepreneurial firms (Murray 2004). These findings should cause us to rethink our views on the mechanisms through which increased public R&D funding may affect firms and make the cost/benefit profile of searching the technical knowledge space for opportunities more attractive for a wider number of individuals. The search perspective shows two different mechanisms through which we might see the external environment shift the initial variation in the choice of an innovation strategy (or subsequent R&D intensity). The first is through influencing the labor market for entrepreneurs such that a greater number of those individuals who are more likely to search the technology space for new business opportunities (because they have lower costs or higher expected rewards to searching this space) choose to become entrepreneurs. The second is through directly lowering the search costs or increasing the expected rewards to searching the technology

---

8 It should be noted that evidence for this more subtle view of the relationship between scientific and technological networks and activities has been found using patent and citation data as well (Gittelman, Kogut 2003).
knowledge space by generating newer, higher mean distributions to search along, or by acting as a map to narrow down the best distributions to search along in applied research. In other words, changes in the external technical knowledge environment (via public R&D expenditures) may shift the landscape or shift the distribution of starting points for those individuals who tend to become entrepreneurs. In the language of those who model search processes through NK models, public R&D expenditures can alter both the landscape and potentially the starting points of the entrepreneurs.

Separate from altering the costs and expected benefits to searching technology knowledge space for opportunities, an individual’s work experience may have a different effect. The type of problems that people will come across and be motivated to try to solve will differ by the experiences that they have on a daily basis (Von Hippel 1998, 2005). Also these problems will tend to correlate with the toolset that the individual is working with. A chemist is more likely to both come across a problem related to chemistry and to have the tools or easier access to the tools and knowledge to solve that problem than a software engineer. Through the case study of one MIT technology, it has also been shown how prior experiences shape the opportunities that individuals see in a given technology (Shane 2000).

Since it tends to fund more open-ended research, grant-based public R&D will suggest more possible distributions to search for product/market opportunities in applied research. These additional possible distributions will be easier for R&D employees to see than for top management, causing the type of disagreements modeled by Klepper (2007) and resulting in greater levels of entrepreneurship among those R&D employees who then are more likely to found firms with an innovation strategy to search along those new distributions.

In the sections that follow, the theoretical views on the effects on innovation of financial
constraints and of science and technology investments are reviewed. Next, the empirical
literature is reviewed to see where the field stands in providing evidence for or against the
theories of financial constraints versus public R&D impact on industrial innovation.

**Financial Constraints**

Besides a search for profitable ideas, managers and entrepreneurs also must engage in a
search for funding to develop those ideas. If funding is costly or difficult to find, then knowing
this a priori could influence the types of ideas that are pursued and the strategy chosen to be
those that are lower cost. Research and development activities are widely believed to be under-
financed in a competitive market (Arrow 1962, Nelson 1959, Schumpeter 1942). There are two
approaches to solving this problem. The first is direct government provision of R&D; the second
is aimed at increasing the flow of funding to private R&D. Even if problems with
appropriability are solved, there is still a second part of the market failure in R&D investment.
The underinvestment in private R&D occurs when the cost of external capital may be higher than
the private rate of returns to R&D. As we discuss below, information asymmetry and moral
hazard play a role in raising the required rate of return for R&D investment (Arrow 1962; Leland

The cross-country relationship between financial conditions and growth is relatively well
established. Much of the work on financial constraints focuses the choice of individuals to enter
into self-employment (e.g., Evans, Jovanovic 1989, Gentry, Hubbard 2000, Nanda 2007, Aghion,
Fally, Scarpetta 2007) or on the effects on established firms (e.g., Banerjee, Munshi 2004;
Fazzari et al. 1988; Kaplan and Zingales 1997, 2000; Moyen 2004; Paravisini 2008). While they
do not go into the mechanisms, Cooley and Quadrini (2001) show that a model incorporating
financial market frictions can also fit the existing stylized facts on firm growth and market
Bougheas and coauthors (2003) create a dynamic programming model where R&D investment is liquidity constrained due to the fact that the returns of R&D projects are much more variable than returns of other types of investments. Bond et al. (1999) use an error correction model of the long-run target level of the capital stock. They note that R&D investment is unique since it involves significant sunk costs and large adjustment costs since much of R&D spending goes into the wages of R&D personnel. These unique characteristics are expected to result in the smoothing of R&D investment by firms, resulting in dampened reaction to shifts in the prices of inputs into research.

The financial capital requirements associated with founding a new firm and particularly the extra costs associated with developing a new technological innovation can be expected to further constrain the transition to entrepreneurship. Research in entrepreneurial finance has focused on the venture capital industry (e.g., Gompers and Lerner, 1999). Theory and empirical evidence support the idea that asymmetric information, asset specificity and the resultant agency and monitoring costs do seem to drive the structure of venture capital agreements as a special type of financial intermediation (Gompers 1995).9

Kortum and Lerner (2000) build a theoretical model based on a production function for

---

9 The birth of formal venture capital organizations can be traced to the formation of American Research and Development Corporation in 1946 (Hsu and Kenney, 2005), which coincidentally focused initially upon financing commercially oriented R&D to move academic and governmental ideas towards the market. The size of venture capital disbursements and fundraising has grown dramatically but with high volatility since that time (Kortum and Lerner, 2000; Kortum and Lerner, 2000; VentureOne, 2000). In 1979 an amendment to the “prudent man” rule by the Department of Labor allowed pension managers to invest in high-risk assets, including venture capital, thus sparking a rise in VC, while efforts at commercializing the Internet are largely responsible for the late 1990s spike in VC investments. In the years since 2000, following the bursting of the technology bubble and September 11, 2001, the levels of venture investment were $28B in 2008 and $3B in the first quarter of 2009 (in comparison to a peak of about $100B in 2000) according to the National Venture Capital Association, [http://www.nvca.org/ffax.html](http://www.nvca.org/ffax.html) (accessed April 20th, 2009).
ideas. The key assumption in their model is that there is a distribution of possible research projects, some of which are more suited for development in a corporate R&D lab and some more appropriate for funding in an entrepreneurial setting by a venture capitalist. Raising the proportion of funding from venture capital through government intervention pushes VCs into a portion of the distribution closer toward the end of this spectrum where corporate R&D labs are assume to have a cost advantage. So it is not immediately clear that society benefits from such an intervention. Along with 3 other key assumptions, they assume a term $\lambda$, that captures how radical a technological innovation is and posit that a more radical innovation lowers the cost of commercialization in an entrepreneurial setting, in contrast to a corporate setting.

Kortum and Lerner use this model to derive equilibrium levels of venture capital funding. They find that venture capital funding is higher when the cost of raising venture funds is lower and when a higher proportion of the technological opportunities are radical in nature. A point to which we will return later is that if public R&D expenditures are more likely to open up technological opportunities that are relatively more radical in nature, then an increase in public R&D would be expected to lead to a corresponding increase in the equilibrium level of venture capital.

There may be economic justification for subsidizing or encouraging venture capital as a financial institution under several conditions where the level of venture capital is thought to be below efficient equilibrium levels: (a) paths to liquidity such as initial public offers or acquisitions are difficult; (b) evaluating or protecting intellectual property is more costly; or (c) other legal or institutional reasons have significantly increased the cost of venture funds. However, in practice, it is clearly difficult to distinguish these justifications from a low level of VC resulting from fewer radical technological opportunities. Coming back to the assumptions in
the model, it is not immediately clear why venture capitalists should have an advantage in
developing radical innovations or what barriers keep corporate lab managers from imitating these
advantages. Jensen (1993) argues that one explanation is agency problems on the part of
corporate industrial research labs. In general, there are four theoretical mechanisms through
which we tend to think that venture capital is a unique form of financing for innovation: 1)
Screening: VCs specialize in scrutinizing founders and their business concepts especially when
assets are soft and information asymmetries are high; 2) Monitoring and control: VC’s stage
investments and take board seats to provide an additional level of corporate governance; 3)
Active: in terms of providing mentoring, strategic advice, networks, professionalize the company
(Hellmann and Puri, 2000); and 4) VCs have been shown to influence the exit decisions of
entrepreneurial firms towards an initial public offering (Lerner 1994; Gompers, 1995). It
seems reasonable that the search for funding may constrain the choice of an innovation strategy,
or those who are better connected to external sources of funding may feel that they can then
expend greater resources searching for and developing ideas utilizing new technology.

Next, I look at the theoretical arguments related to how shifts in the technical labor
market and knowledge environment might affect the adoption of an innovation strategy.

Theoretical arguments for S&T – from ideas production function in economics

Much of the thrust for the theoretical arguments for the economic growth effects of
science and technology come from the Romer (1990) and model of endogenous growth and the
ideas production function. Blank and Stigler (1957) also did much earlier work on the labor
market for scientists and engineers. The most simplified, basic idea behind the Romer model is

\[ 10 \] While a strong stock market is a determinant of VC distributions, there is some evidence that an initial
public offering could reduce firm innovation (Wu, 2009).
that the flow of new ideas (innovations) is driven by both the stock of human capital and the previous stock of ideas in the economy. In this way, a virtuous cycle develops of increasing investments in innovation driving higher returns to future investment and continued growth.

Porter and Stern (2004) modify the production function to separate country-specific knowledge stocks. Most of the work building on this model has been highly aggregated and mathematical. Nonetheless, it has inspired a large literature and efforts to “peer further into the black box” and move to less aggregate levels of analysis at the industry and firm levels.

Figure 1 shows that the level of R&D investment is determined by the marginal benefits of applied R&D (which may be increased by more basic, public R&D) and the marginal costs of R&D (which may be decreased by easier access to venture capital or other funding sources). The relative importance of each factor will depend on the mechanisms through which each type of effect acts and more importantly by the shape each of the two curves. Firms who do not engage in R&D can be thought of as having a MCC curve that is above the MRR curve at all points.

Figure 1

![Figure 1](image-url)
David and Hall (2000) reviewed the literature on public-private R&D interactions and offer a useful framework for the existing theoretical literature. They note that there has been underinvestment in sorting out the channels and mechanisms of influence involved, so I will focus first on the theoretical literature and then subsequently on the empirical evidence. The economic literature in this area is mainly concerned with whether public R&D expenditures and private R&D are complements or substitutes.11 David and Hall divide up the mechanisms flowing from public to private R&D (they ignore reverse flows) according to three dimensions. First, they note that there are direct and indirect effects of public R&D. Direct effects include shifts in the demand and supply of tangible inputs used in the R&D process (scientists, engineers, and research tools). Indirect effects involve the intangible results of the R&D process. The indirect effects stem from the knowledge generated as a result of public R&D and the effects that knowledge has on the expected costs and benefits of privately funded R&D. Broadly, these are the “knowledge spillovers” that a large literature has developed around. The direct and indirect effects are not rigorously mutually exclusive. For instance, knowledge spillovers will have an influence on the prices of inputs into the research process and new knowledge can become embedded in research tools. The second dimension is on the mechanism through which public R&D expenditures are disbursed. When grant R&D is given, at least in the U.S. practice, it is typically for more exploratory research to university labs or national institutes. At the other end of the spectrum is contract R&D that is often given to private firms or government labs and is typically for a more defined mission of one of the public agencies (Department of Energy, Department of Defense, etc.). Contract R&D, in the sense that it transfers funds from the government to private firms, intuitively appears more like relaxing financial constraints on firms.

11 David and Hall (2000) take up the question of whether “crowding out” of private R&D by public R&D is necessary a negative thing and why one might be concerned about the substitution vs. complementarity debate.
but in a more targeted manner to subsidize the performance of R&D. We might expect that its effects are similar then to a reduction in financial constraints, except that the government may not act in the same ways that profit-seeking financial intermediaries might be expected to operate.

It is important to examine the extent to which grant and contract-based mechanisms of public R&D expenditure differ in other countries.

Third, the effects of public R&D expenditures may be felt in different ways according to different lags. For example, contemporaneous effects of increased public R&D funding may be to increase the demand for scientists (or other research inputs) in a certain specialty, increasing their salaries and labor costs to private firms (Goolsbee 1998). The short-term effect could be for private firms to react to higher labor costs by decreasing the number of scientists hired. However, with a longer lag, supply will catch up with the increased demand and salaries may fall, particularly if public demand subsequently decreases or shifts to new areas. In addition, the knowledge generated by these scientists may (with a lag) increase the productivity of more applied private R&D, resulting in private R&D funding increases. David and Hall (2000) walk through several examples of the complex interactions between short-run and more dynamic effects along the three dimensions. For instance, public R&D could also be interpreted by firms as a signal of future demand, resulting in contemporaneous increases in private R&D to build absorptive capacity and to take advantage of future demand (Cohen, Levinthal 1994, 1990, 1989). They then undertake some more formal modeling of the mechanisms. The overall message is a cautionary one on the ability to use aggregate data to disentangle the net impacts or whether public R&D is likely to stimulate or crowd out private R&D funding. Nonetheless, the analysis supports the idea that if complementary effects are to be found, they would be more likely in grant-based R&D and with a considerable lag. Contract-based public R&D and the short-run
effects are more likely to crowd-out private R&D investment.

Although to our knowledge the issue has not been discussed in previous literature on public R&D, the effects may also act through different mechanisms for established firms versus newly founded firms. The prior literature has focused on effects operating on established firms. However, if evolutionary models are valid or other models (involving adjustment costs) that posit persistence in R&D intensity by firms, then the larger effects may be those on small firms or potential entrepreneurs.

Figure 2 (parts a and b) shows the conceptual model we have in mind of the interactions between the search process for product/market ideas and the search process for funding.

**Figure 2a**

Klette and Griliches (2000) were among the first attempts to develop a model of R&D investment and stochastic innovation as the drivers of firm growth, based on the quality ladder of Aghion and Howitt (1992) or Grossman and Helpman (1991). However, they acknowledge that their model does not deal well with important aspects of imitation or the large fraction of

---

presumably imitating firms reporting no R&D activity. Klette and Jakob (2004) build a model of innovating firms that both matches many of the stylized facts from firm-level research and is simple enough to aggregate to the macro-level of the production function theories that discuss the behavior of the economy as a whole. The model matches a large number of stylized facts; however, the weakness of the model is that to introduce heterogeneity in firms, it contains an exogenous source of heterogeneity in terms of firms emerging from a distribution of sizes in terms of the innovative steps that they take. So by construction, in their model, the reason why some firms are more R&D intensive than others is because they take larger innovative steps, for unknown reasons. One wonders then why other firms can’t (or choose not to) take larger innovative steps.13 Their model is set up such that more R&D-intensive firms do not grow any faster because larger innovative steps are also more costly. As the authors admit, this is somewhat ad hoc and also inconsistent with other evidence on growth and R&D intensity. In their model, a firm’s innovation rate is a function both of its investment in R&D as well as its knowledge capital. Knowledge capital is defined as the skills, techniques and know-how that the firms draw on in trying to innovate. In their model, these are internal resources (which do not depreciate!) from past innovation attempts. One could also think of them as external knowledge resources from spillovers to private or public R&D, yet this was not the intention of the model.

Lentz and Mortensen (2008) extend the Klette and Kortum model described above to better allow for firm heterogeneity. In their version of the model, worker reallocation drives the growth process and differences between firms. Workers reallocate from working in less profitable firms on obsolete products to firms that have innovated new, more profitable products

---

13 In addition, the Klette and Kortum (2004) model yields the prediction that conditional on the firm’s survival, there is an increasing probability of a larger size. This contradicts common experience of the start-up community where most start-ups become the “living dead” neither growing and providing high return for investors, nor going bankrupt.
through R&D. They decompose the contribution to aggregate growth rates by firm type (incumbents vs. entrants). The model has the restrictive assumption that firms cannot direct their innovation activity toward a particular market, that the capacity to innovate is not specific to any subset of product types, and that entry requires innovation. Their model also shares the drawback of the Klette and Kortum model of containing an exogenous source of heterogeneity in terms of firms emerging from a type distribution that determines the distribution from which they draw innovations. Yet the process driving the determination of firm types is not modeled.

Klepper and Thompson (2006) create a model of submarkets and the evolution of market structure where different technologies, services, customer segments, or geographic areas can represent different submarkets. It is similar to Sutton (1998) and Klette and Kortum (2004) in modeling growth opportunities as appearing randomly to develop a theory of the firm size distribution. The rate of entry into new submarkets is determined by R&D effort (empirical data from U.S. laser industry). However, the model assumes that all entry into submarkets is simultaneous, there is no exit from a submarket until it is destroyed, and all opportunities for growth at the firm level correspond to the creation of new submarkets. One could imagine extending this into modeling a firm’s choice between exploiting different types of submarkets including those requiring some technological innovation and those requiring imitation in a new geographic location or for a new customer segment. Yet this direction is left unexplored. There is a relationship to the firm growth literature, since their model is meant to explain market structure dynamics, not heterogeneity in R&D investment. This type of model can be contrasted with the Jovanovic (1982) selection model (where firms/entrepreneurs are learning signals about their quality) and differences in firm productivity (lower marginal costs) are the source of firm

---

14 Similarly, we are interested in decomposing the effects of shifts in funding sources or public R&D on the firm-level contribution to innovation into effects on continuing firms and selection effects on entrants.
heterogeneity.

While these models represent great progress in moving the highly aggregate models down towards the firm level in a way that incorporates (slightly) more economics and matches not only the empirically observed firm and market growth dynamics, but also the idea that economic growth is driven by R&D. Yet the models all suffer the drawback of not accommodating (ignoring) the observed differences in R&D intensities, whether they are due to production costs, product market competition, and access to finance for innovation, or innovative opportunities across firms. Now that we’ve seen the theoretical literature on the mechanisms through which the funding and knowledge environments may interact with private firm R&D, we will muddy the waters a bit more by looking at the empirical evidence available. Throughout, the reader should keep in mind the caveats mentioned above about the difficulties of inferring net effects when aggregating across multiple dimensions and mechanisms. In addition, since the empirical settings and sampling methods differ widely across studies, it will be important to keep these details in mind when interpreting the results. The various mechanisms at work may differ according to the sample. For example, one mechanism for increased private R&D is an increase in the R&D intensity of industry incumbents. Another is for the industry incumbent R&D to stay constant, but for new entrants to be more likely to choose an innovation strategy. Panel data following a set of existing, public firms would miss the latter mechanism entirely.

**Empirical evidence**

We will only briefly review the empirical evidence. For a more complete review on the public R&D side, see David, Hall, and Toole (2000). Hall (2005) has a review of the literature on the impact of financial constraints on R&D. We will focus on more recent work and work that relates more directly to influences on firm searches for ideas and funding and the influence
on the choice to pursue an innovation strategy.

**Funding**

Even in the best designed studies, testing for financial constraints (much like testing for effects of public R&D on private R&D) is extremely difficult. Perhaps because of this, empirical work evaluating the mechanisms for reduced financial constraints to result in increased entrepreneurship, innovation or growth at the firm level has been rare (Kerr, Nanda 2008).

Employing a five year panel of 179 small public firms in four R&D intensive industries, Himmelberg and Peterson (1994) find a large and statistically significant relationship between internal finance and R&D investment.\(^{15}\) They measure internal finance by firm cash flow and correct for downward bias in the coefficient due to high adjustment costs for R&D using within and between-firm results as well as instrumental variables results (using the first two years of the panel as instruments). Overall, they find evidence for high adjustment costs causing firms to smooth R&D investments.

In a cross-section of Italian manufacturing firms Guiso (1998) finds that firms classified as high-tech were more likely to be turned down for bank loans than low-tech firms. Recognizing the measurement bias in the high tech firm indicator variable, he uses instrumental variables techniques to attempt to address the measurement problems around classifying high-tech firms. However, the instruments have poor fit and are likely to suffer from weak instruments problems. In addition, the choice to become a high tech firm in the first place is not explicitly modeled and is another source of endogeneity.

Bond and Harhoff (1999) use the institutional variation between Britain and Germany as an identification strategy. They find that financial constraints are more significant in Britain and that they primarily affect the decision to engage in R&D rather than the level of R&D spending.

\(^{15}\) The replacement value of its capital stock in 1983 was between $1 million and $10 million.
The strength of this paper is in using cross-country variation in financial institutions as an identification strategy. However, there are several disadvantages in their final sample of around 200 firms in each country. As the authors admit, the firms are representative of large (revenues in excess of DM 32 million, more than 250 employees or balance-sheet in excess of DM 15 million) R&D performers, but not of firms in general. While the authors do much to address them, there are concerns that the results may be driven by other differences between the countries or the unusual historical time period of the sampling.

Kortum and Lerner (2000) estimate a patent production function using panel data for 27 years in the U.S. on venture capital disbursements and patents. To deal with the fact that variation in technological opportunities could be causing upward bias on the venture capital funding estimates, the authors use the industry-specific average of the venture capital funding to privately funded industrial R&D ratio between 1965 and 1978 interacted with a dummy variable which is equal to 1 for each year after the Department of Labor’s policy change. This change was a clarification to the rule that prior to 1979 had limited the ability of pension funds to invest in venture capital. However, they also need to instrument for private industrial R&D as it would also be affected by technological opportunities. Yet, this requires a rather constraining assumption on this instrument (gross industry product) that is only valid if the price elasticity of industry demand is exactly equal to one. Despite additional empirical difficulties that the assignment of patents to industries is inherently imperfect, that VC funding also sometimes is used for low-tech firms or marketing activities and the well-known limitations of using patents as measure of innovation, the authors are extremely careful in recognizing the limitations in their analysis. They find that venture capital accounted for 14% of U.S. innovative activity and that a dollar of venture capital stimulated three times more innovation than a dollar of private firm
Bougheas and coauthors (2003) use firm-level data for manufacturing firms in Ireland and find evidence of liquidity constraints. The data they use has the advantage of covering all firms in Ireland with more than 20 employees. However, it covers only research active firms, enabling them to detect changes in R&D expenditures, but not in those firms performing R&D at all. The identification of their results relies on comparing investment levels (using internal funds) in physical capital and R&D. The assumption is that if firms are constrained from raising external capital for R&D (but not physical capital) then R&D investment should be correlated with past profitability, but this relationship should not hold for physical capital. While the coefficient on past profitability is significant and positive in predicting R&D investment levels and it was not statistically significant for physical capital. Yet, with their sample of just over 500 firms across manufacturing industries (mostly in the cross section), they are not able to show that these two coefficients are significantly different from one another. This result makes it difficult to conclude that R&D investment is more constrained than investment in physical capital, which was meant to be the key test. Nonetheless, the results do offer one of the few tests using data outside of the U.S. context.

Levitas and McFadyen (2009) find in a sample of biotech firms that liquidity constrained firms can use patents to partially overcome the information asymmetries that are one sources of higher costs for external capital. In this way, these firms appear to reduce their need to hold excess liquid assets in order to fund R&D expenditures. However, it could also be the case that firms that patent more have lower costs of external capital because they are higher quality firms, have more secure appropriability of their R&D investments or for other reasons.

Since the Small Business Innovation Research (SBIR) program is a government
mechanism to provide funding for contract-based research in private firms, it is a good transition point to reviewing the empirical studies on various mechanisms of public funding of R&D. Wallsten (2000) examines the question of whether public contract-based R&D funding encourages or crowds-out private R&D. Using a sample of firms that won SBIR funding, a sample of firms denied funding and a sample that was eligible but did not apply, he uses instrumental variables techniques to control for the endogeneity of awards. The concern is that if a firm is already doing more R&D, then it may be more likely to win an award, causing a spurious correlation between awards and R&D. The results show that SBIR funding crowds out firm-financed R&D dollar for dollar (as we expected for contract-based funding). However, as the author acknowledges, the non-SBIR firms are not a representative sample, so projecting out of sample to what would have happened to eligible firms had they applied or to denied firms had they received an award is not possible.

Unlike most of the studies in this area, Lerner (1999) uses a sample of 1435 firms that received SBIR awards and a matched sample of firms that did not. The firms are mainly private so profitability and valuation data are unavailable. Nonetheless, in terms of employees, the SBIR funded firms (particularly those in regions with venture capital activity) are found to grow faster than the non-SBIR firms. Lerner attributes this effect to “certification” by the government allowing these firms to raise more private funding in geographic areas where such funding is available.

Hall (2002) surveys the empirical literature on financial constraints for R&D and finds that small and new innovative firms experience high costs of capital but that the evidence for high costs of R&D capital for large firms is mixed. Her conclusion is that the VC solution is limited to certain sectors and those settings with thick markets for acquisitions and IPOs, while
the government incubator and seed funding solutions need further study. She notes that using cross-country variation is a particularly desirable method to make progress on these issues because the outcomes may depend on institutional factors that are difficult to control for with single-country data.\footnote{She urges further study of programs to increase funding for young firms using quasi-experimental methods.}

**Public R&D**

David and coauthors (2000) review the econometric evidence for whether public R&D is a complement or substitute for private R&D and conclude that the existing findings are ambivalent due to inadequate specification of the “experiment(s)” that investigators have used and unclear theoretical models of the mechanisms involved. Following their framework, we begin with the empirical evidence on the “indirect effects” that public R&D has through increasing the stock of knowledge and the expected returns to private R&D followed by the empirical evidence on the direct effects on the inputs used in the R&D process.

There has been an extensive empirical literature on the indirect effects known by the term “knowledge spillovers” and since these studies have been reviewed elsewhere, we only briefly mention the results and empirical difficulties (Jaffe 1996, Griliches 1992). The stream of research on knowledge spillovers from academic research is impressive and the evidence seems consistent in linking at a local geographic level, university R&D and publications with increased patenting by firms and citations to those university publications (Jaffe 1989, Jaffe, Fogarty, Banks 1998, Jaffe 1996, Henderson, Jaffe, Trajtenberg 1998). In this sense, there appears to be evidence supporting the view that public R&D does generate knowledge that is economically useful to firms and perhaps that increases the productivity of private firm R&D (Barnes et al. 1998, Mowery et al. 1998, Kim et al. 2005). The studies use data on university patents and
citations to these patents to quantify knowledge spillovers from academic science. However, this latter point is still subject to much skepticism on the econometric evidence offered thus far. However, if most of these citations are due to academic science funded by private firms, then labeling this correlation a “knowledge spillover” seems incorrect, especially if it is private funding that is spilling over to the university (Breschi, Lissoni 2001). It is not clear whether the localized citations to academic science are due to formal contracts between firms and local universities (which we would tend not to think of as spillovers) or whether they are due to spillovers in the sense that we typically tend to think of them as occurring.

Also under the category of indirect effects, Agrawal (2001) reviews the economic literature on university to industry knowledge transfer. He divides the work into four areas. To very briefly summarize, work on firm characteristics has focused on absorptive capacity and research on university characteristics has mainly dealt with the Bayh-Dole act. The work on geography in terms of spillovers has shown that they tend to be localized and he notes that research on “channels of knowledge transfer” has focused on patents and citations, offering great opportunities for work with a greater variety of research questions and examining other mechanisms or data sources.

Klette and Griliches (2000) use a sample from Norway of 265 line-of-businesses across six years for three high-tech industries. They find evidence consistent with their model of endogenous firm growth based on R&D investment. However, the data contain only observations with at least 20 employees and non-zero R&D investments and only the same set of firms (many of whom exit the survey) over the six years, so they cannot extrapolate to the behavior of newly founded firms.

Furman and coauthors (Furman, Porter, Stern 2002) are one of the few papers to examine
the correlation between aggregate country-level patenting and measures of public R&D expenditures and access to venture capital funding. Using a sample of 17 OECD countries, they find that various lagged measures of public R&D (for example, the share of GDP devoted to higher education, aggregate science and technology personnel, and the percentage of R&D performed by universities) are associated with higher levels of patents granted in the United States. Further, they find that the coefficient on the measure of venture capital availability (average rating of executives of the strength of venture capital availability) was not significantly different from zero, indicating that the perception of venture capital availability was not associated with higher patent production. In a follow-on paper, Furman and Hayes (2004) find that similar measures of investment in R&D and in science and technology personnel are associated with higher levels of investment in those countries that experienced substantial increases in innovation over the time period. The authors caution that a causal interpretation cannot be made from these data however. As David et al. (2000) discuss; this analysis does not break out the mechanisms of the type of public R&D expenditures or the possible lags through which different mechanisms are working. Yet, the analysis is suggestive that public R&D investments are associated with greater country level patenting at the technology frontier.

Lentz and Mortensen (2008) use a sample that follows a cross-section of privately owned firms drawn from the Danish Business Statistics Register for the years 1992–1997. The sample of approximately 4,900 firms is of those with 20 or more employees. The sample does not include entrants. The only variables observed in each year include value added, the total wage bill, and full-time equivalent employment. In order to get identification from this small set of variables, the structural model relies on some heroic assumptions including aggregate firm creation equals aggregate firm destruction and that entrants face the same innovation cost
function as the incumbents. They find evidence supporting the idea that the firm growth
dynamics are driven by worker reallocation from less to more innovative firms. While
interesting, this is somewhat dissatisfying since firm innovation is still driven by an exogenous
draw of firm innovation quality types.

Using U.S. patent data, Balasubramanian and Sivadasan (2008) provided evidence in
favor of the Klette and Kortum (2004) model of innovation and firm dynamics by investigating
the direct impact of patenting activity on firm size and measured productivity. The authors
interpret their results as supportive of the class of theories modeling firm growth as driven by
new product innovations rather than by a reduction in the cost of existing products (firm
productivity). However, while patent data may be a proxy for product innovation, it is less clear
that firms use patents as a mechanism for appropriation at the same rate for process innovations,
which are easier to keep as trade secrets.

Da Rin and coauthors (2006) use a sample of venture capital investments in 14 European
countries between 1988-2001 to assess various policy instruments for encouraging active venture
capital markets. Using the 187 observations in their data, they predict the ratio of early-stage
investments and of investments in “high-tech” sectors to total investments. They find changes in
labor regulations, the corporate capital gains tax, and the creation of stock markets targeting
small firms to be effective. They find no evidence of a correlation with total country-level public
R&D (where this measure includes all business and government, contract and grant-based
funding, and university R&D) contemporaneous with the measured VC investment. However, it
is not clear that the dependent variables of early-stage investments or investments in their
designated “high-tech” sectors represent better functioning venture capital markets or more
innovative firms.
In one of the few micro-level studies of the impact of federal R&D funding on private R&D, Mansfield and Switzer (1984) examine 41 federally-funded grant-based R&D projects related to industry. They find that according to the companies themselves, 20 percent of the R&D would have been done in the absence of federal R&D. In one third of the cases, additional follow-on research was performed by the firms outside of the scope of the federally funded R&D.

Lach (2002) uses data from Israeli manufacturing firms and finds evidence that Ministry of Industry and Trade R&D subsidies had a large complementary impact on small firm R&D, but a small and statistically insignificant negative (substitution) effect on the levels of large firm R&D. Branstetter and Ogura (2005) analyze U.S. patent citation data and present results supporting the idea that there has been an increased emphasis on the use of knowledge generated by university-based scientists by those seeking to innovate in industrial settings. They find that bioscience-related inventions form much of the increase in the contribution of knowledge spillovers from academia (as measured by patent citations to academic papers). Similarly, Cassiman and Veugelers (2006) argue that a firm’s reliance on basic R&D conditions whether public R&D investment will be complimentary and stimulate further private R&D investment. However, exactly what determines a firm’s reliance on basic R&D is not modeled.

Rothaermel and Hess (2007) develop a multi-level model of innovation and shows that both the individual and network levels both significantly increase patenting in biotech. The results indicate that individuals matter, but also their connections to the larger external pool of knowledge, supporting the idea that connections to the external knowledge environment may condition innovation strategy decisions by increasing the productivity of searches for technological opportunities.
Model of Two Firm Search Processes

Figure 2b shows a schematic diagram of the relationships that we have in mind between initial conditions, effects on the market for inputs into the R&D process, and the way in which firm search processes are shaped by these factors. The results of the firm search processes then go on to determine firm strategy and the resulting performance or survival.

Figure 2b

Our starting point is the Romer (1990) ideas production function.

\[ \Pr(I_{it}=1) = \left( \delta H_{Ait} A_{it}^\phi \right) / C(V_{it}, \pi_i) \]  

(1)
Following Romer’s (1990) model of the ideas production function, we make minor modifications to bring the model down to the firm level. Our model predicts the likelihood that a firm undertakes an innovation strategy in choosing to pursue a profitable opportunity that involves a technological innovation. The probability depends on the relative ease of the search for an idea and the search for adequate funding to develop and commercialize that idea. The variables are indexed by $i$ to indicate the firm and by $t$ to indicate the founding year. $A$ is a measure of the total stock of knowledge/ideas and $H_{Ai}$ is the quantity of human capital in the ideas-producing sector. $\dot{A}_{it}$ represents the flow of new ideas (innovations), which is driven by both the human capital, and previous stock of ideas in the economy (scaled by a factor $\delta$).

Following Porter and Stern (2004), we modify this production function by disaggregating the world knowledge pool into separate domestic (country) knowledge stocks. $H^{\lambda}_{Ai}$ is a firm-specific component indicating the ease of search technology space relative to other spaces for profitable opportunities. Similarly, $A^{\phi}_{it}$ can be thought of as representing the stock of previous ideas, or as the ease of finding a profitable innovation opportunity relative to other types of opportunities. Define $C(V, \pi)$ as the search costs for funding an innovation project relative to any other project.

$$C(V, \pi) = 1/(\pi V)$$

where $\pi = (0,1)$ and where $\pi$ a firm-specific component based on the ties or ability of the founders to raise funding quicker. Define the level of VC funding as $V$.

$$V = \rho \theta A_t$$

Following Kortum and Lerner the level of VC funding is partly determined by the proportion of new technological opportunities that are radical in nature and thus more appropriate for venture funding. We multiply by a factor $\theta = [0,1]$ that represents the idea that
there are financial frictions (due to information asymmetry or moral hazard) that reduce the available funding from the efficient levels. We model public R&D as increasing the proportion of technological ideas that are radical in nature (multiplied by a scale factor $\rho$). The idea is that public R&D adds to human capital, knowledge stock and the level of VC funding through its effects on producing a higher proportion of more radical ideas. Equation 1 becomes the following:

$$Pr(I_t=1) = (\delta H^{k_{At}} A^\phi_t) / [1/(\pi \rho \theta A_t)]$$  \hspace{1cm} (2)

One can observe an increase in a country’s flow of new ideas via two mechanisms. One is through existing firms that are already doing more innovation because of an increased productivity of research activity. This mechanism implicitly assumes that either all firms are innovating or that the proportion of innovating firms remains constant. The second mechanism is through the process of creative destruction where new firms are created and because of the increased productivity of R&D, a higher percentage of these new firms elect to take an innovation strategy. In this way, a higher proportion of firms in the economy are undertaking innovation activities. We further disaggregate to the level of the firm, and model an entrepreneur choosing between an innovation strategy and an alternative business strategy (based on lower costs, or imitation).

The theoretical model is meant to reflect the idea that there are two different effects through which the external environment affects the two searches that firms engage in. The first is through conditioning who decides to start a business and this selection may shift the likelihood of an innovation strategy (the $H^{k_{At}}$ component). Public R&D investment (with a lag) impacts the labor market for scientists and engineers and specialized financial intermediates such as venture capital can shift the search costs for R&D personnel to find funding. Second, the environment

34
may shift the relative attractiveness of an innovation strategy for everyone through direct and indirect effects on the productivity of private R&D or the cost of inputs into the research process (for example, funding, technical labor, or research tools). We acknowledge that there are several ways for a firm to grow (or spaces for them to search for growth opportunities). These include search for profitable opportunities in new customers (geographic location or market segment), new products or services, or through imitating products or services. We limit our analysis to comparing an innovation strategy relative to all other types of strategies and leave to future scholars, the direction of disentangling the other strategic choices.

**DISCUSSION**

Innovation takes place in almost every country and location on the globe. Since regional and national government leaders perceive innovation to be a driver of economic growth, they are eager to replicate the clusters of technology-based entrepreneurial firms that have tended to be concentrated in just a few places in United States. Entrepreneurs often find themselves stretched between (1) spending time developing their new ideas and (2) spending time raising money so that their ideas can live to see the light of day. The main contention of this paper is that these two problems are linked and that more research can shed light both on effective search strategies for ideas or money and on the macro-level development of innovation.

Venture capital is commonly believed to have promoted the development of innovative start-ups and fostered the growth of the U.S. economy (Hellmann, Puri 2000, Kortum, Lerner 2000). The search for the main drivers of technology entrepreneurship has frequently led to calls for spreading venture capital around the globe (European Commission, 1995; China Daily, 2007),
to the proliferation of science parks, and to university courses to train future entrepreneurs. Even now with the debates over stimulating the economy, many point to the lack of lending to small businesses and the importance of the entrepreneur in turning the economy around. Yet we have little systematic evidence on the relative importance of various purported drivers of technological innovation.\(^\text{17}\) In contrast to the long line of literature on venture capital and liquidity constraints and innovation, the relationship between public R&D expenditures and innovation in entrepreneurial firms has not been systematically scrutinized.

Further analysis points to potential ways to get around the limitations in the environment. One example is to add founding team members or early employees with connections to the resources in short supply in the local environment. Kerr (2008) shows how ethnic scientific communities and networks can be used to transfer scientific knowledge. Similarly, Nanda and Khanna (2009) show that local entrepreneurs in India rely significantly more on diaspora networks for financing and business leads. This is particularly the case if they reside in more resource poor locations. Countries, like China (or India) with a large overseas diaspora may be better able to overcome limitations in financial institutions, though this is beyond the scope of this paper. Agarwal (2009) begins to address some of these issues by calculating the theoretically optimal diaspora size.

The contribution of this paper is in delving into the micro-foundations of the increasingly well-established links between institutions and growth. Institutions could be legal (contracting – (Acemoglu, Antras, Helpman 2007; Azoulay, Shane 2001; Zhao 2006) (Murray, Stern 2005), financial (Kortum, Lerner 2000) or public science and technology institutions (Furman, Porter, Stern 2002, David, Hall 2000). Increasingly, we have macro-level studies of each, but scare

\(^{17}\) The details of the structure of government programs to encourage venture capital have been shown to shape their success as well (for a case study of the Israeli experience, see Avnimelech, Teubal, 2006).
micro-level data showing how these factors actually impact firms and individuals. Scholars of institutions may benefit from more closely linking the mechanisms through which institutions are thought to affect firms with the details of the internal organization and processes that are found within firms. Also, there is a tendency in the institutional literatures to focus on a set of effects of institutions on large, existing firms (because this is where large datasets are available) without consideration of the dynamic processes generating variation and selection that resulted in this set of firms. The latter dynamic processes may be where the impact of the institutional environment on firm strategies is largest.

Perhaps the most important contribution of this paper is that it fits several different economic literatures under the common framework of evolutionary theory or search theories. Where the initial stage of firm variation in terms of strategy and resources can be modeled as a search process over different types of resources in the environment. Both the founding team (in terms of their costs of searching different dimensions of the environment) and the initial conditions of the environment shape the dynamic processes of resource identification and accumulation. Previously, this step has been seen as simply having better information or luck, but there is a more systematic logic to who finds what resources and pursues which strategy. Scholars should focus more attention on the intermediate step of how initial conditions condition the choice of strategy and what resources or capabilities to develop, before jumping to conclusions about links between the environment and performance. One anecdotal quote from one of the entrepreneurs we interviewed in Xi’an speaks to this issue.¹⁸ He said,

¹⁸ These survey data were combined with interviews. The Tsinghua Alumni Association set up 42 interviews in Beijing, Shanghai and Xi’an. Interviews were requested with technology entrepreneurs, including some who had not been successful. The representativeness of these interviews cannot be established and primarily those who did become entrepreneurs were interviewed. Presumably any bias might be more on the basis of performance than on the basis of reasons for selection of specific strategies,
“Strategy-making is different in China than in the US. In China you pick up a person who has resources, then you choose the appropriate field to enter then you come up with the strategic goals, then the vision. In the U.S. I feel it is the opposite.”

What is surprising here is that we typically tend to think of strategy driving accumulation of resources. Instead, we have told a story where the resources in the environment drive the selection of strategy. From prior literature, would expect financial resources to matter more for innovation, but we show that with good ideas, money will flow. Finally, theories involving search can fruitfully consider the impacts of the various dimensions of the environment on search activities, rather than focusing too narrowly inside the firm.

Future research should explore in more detail the optimal mechanisms to ease the search, both for technological innovations and for funding to execute on them. Along these lines, Lerner (2002) reviews many of the difficulties and pitfalls resulting from public efforts to play an active role in financing new firms in high-technology.

Future work should examine the performance implications of different types of individuals choosing an innovation strategy in various environments. Also, it would be interesting to look in more detail at the use of different strategies. Future work could look at categorizations of types of innovation strategies including process, product or business model innovations. In addition, future scholars could separate the different non-innovation strategies out and see what kinds of external conditions shape the use of low cost or other types of differentiation. To further test the theory in this paper, experimental methods influencing the search costs for funding or for ideas could fruitfully be used.

however, our request to talk with technology entrepreneurs most likely weighted the sample towards those taking an innovation strategy.
Conclusion

In the span of history, only in relatively recent decades have organized research and development activities begun to use substantial portions of society’s resources (Lenoir 1998). The characterization is even clearer in the case of the institutions of open science (David 1998). Yet, despite the fact that societies around the globe are devoting ever larger percentages of their budgets to basic research, compared with the literature on corporate R&D, we still know relatively little about the linkages between public research expenditures and firm innovation strategies. In recent years, cutbacks in basic science funding in this country have led to warnings about the impact on young investigators and future scientific progress (Zerhouni 2006). The linkages between public R&D and industry are complex and multi-faceted, yet the challenges are not so daunting that they cannot be better understood for the benefit of firms and of technical or economic progress. Theory and our evidence support the argument that entrepreneurs undergo a search for ideas and a search for funding. Yet previous work has offered little guidance for the entrepreneur struggling with these two full-time jobs and asking which to prioritize. While it is clear that there are multiple paths to firm innovation and a range of institutions and environments that support innovative activity, whether the choice of an innovation strategy appears to be more constrained by the search for profitable technological opportunities than by the search for funding remains unclear in the existing literature despite multiple decades of research related to the topic.
FIGURES AND TABLES

Figure 1

Rate of Return

MRR
(derived demand
for R&D)

R*

MCC
(marginal
cost of R&D)

R&D
investment
References


Cassiman, B., R. Veugelers. 2006. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. MANAGEMENT SCIENCE 52(1) 68-82.


March) 71-87.


