Chapter 2
Motivating Entrepreneurship and Innovative Activity: Analyzing US Policies and Programs

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2.1 The Role of Innovation Policies in the United States[1]

2.1.1 Knowledge, Entrepreneurship, and Innovation

Government policy has undertaken a number of key initiatives, such as the Small Business Innovation Research (SBIR) program, the Advanced Technology Program (ATP), and the Defense Advanced Research Projects Agency (DARPA), with the goal of developing the innovative capacity and overall economic performance of the country. These agencies not only help firms innovate where they otherwise would most likely not have, but they also help to address the current and future needs of government agencies for innovative solutions. In order to understand how and why government intervention is needed, the chapter offers an explanation of why R&D and innovation necessitates governmental support.

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2.1.2 The Role of Knowledge, R&D, and Innovation

In what Zvi Griliches (1979) formalized as the model of the knowledge production function, the firm is assumed to be exogenous. The strategies and investments of the firm are then modeled as choice variables generating innovative activity and are therefore modeled as being endogenous. Thus, the model of the firm knowledge production function starts with an exogenously given firm and examines which types of strategies and investments generate the greatest amount of innovative output. Griliches, in fact, suggested that it was investments in knowledge inputs that would generate the greatest yield in terms of innovative output.

Griliches' seminal article prompted a large number of studies, which attempted to empirically test the knowledge production function. These studies were confronted with numerous measurement concerns. The innovative output had to be measured and knowledge inputs had to operationalized. While the economic concept of innovative activity does not lend itself to precise measurements (Griliches 1990, 2002), scholars developed measures such as the number of patented inventions, new product introduction, share of sales accounted for by new products, productivity growth, and export performance as proxies for innovative output. Developing measures that reflect investments in knowledge inputs by the firm proved equally challenging. Still, a plethora of studies (Cohen and Klepper 1992a, b; Hausman et al. 1984) developed proxies of firm-specific investments in new economic knowledge in the form of expenditures on R&D and human capital as key inputs that yield a high innovative output.

2.1.2.1 Cohen and Levinthal's Absorptive Capacity Argument

The literature empirically tests the model of the knowledge production function generated as a series of econometrically robust results which substantiated Griliches' view that firm investments in knowledge inputs were required to produce innovative output. Cohen and Levinthal (1989) provided an even more compelling interpretation of the empirical link between firm-specific investments in knowledge and innovative output. According to Cohen and Levinthal, by developing the capacity to adapt new technology and ideas developed in other firms, firm-specific investments in knowledge such as R&D provide the capacity to absorb external knowledge, termed *absorptive capacity*. This key insight implied that by investing in R&D, firms could develop the absorptive capacity to appropriate at least some of the returns accruing to investments in new knowledge made externally by the firm. This insight only strengthened the conclusion that the empirical evidence linking firm-specific investments in new knowledge to innovative output verified the assumptions underlying the model of the knowledge production function.

2.1.2.2 The Individual Entrepreneur

Audretsch (1995) challenged the assumption underlying the knowledge production model of firm innovation by shifting the unit of analysis away from the firm to the individual. In this view, individuals such as scientists, engineers, or other knowledge workers are assumed to be endowed with a certain stock of knowledge. They are then confronted with the choice of how best to appropriate the economic returns from that knowledge. Thus, just the appropriability question, identified by Cohen and Levinthal (1989), confronts the firm; an analogous appropriability question confronts the individual knowledge or skilled worker.

The concept of the entrepreneurial decision resulting from the cognitive processes of opportunity recognition and ensuing action is introduced by Eckhardt and Shane (2003) and Shane and Venkataraman (2000). They suggest that an equilibrium view of entrepreneurship stems from the assumption of perfect information. By contrast, imperfect information generates divergences in perceived opportunities across different people. The sources of heterogeneity across individuals include different access to information as well as cognitive abilities, psychological differences, and access to financial and social capital.

2.1.2.3 The Geographical Dimension

Recognition of the role that firm-specific knowledge investments could play in accessing, absorbing, and transforming external knowledge, and therefore enhancing the innovative output of the firm, triggered an explosion of studies which focused on potential sources of knowledge that are external to the firm. Some studies examined the role of licensing, cooperative agreements, and strategic partnerships, all of which involve a formal agreement and a market transaction for the sale of knowledge. Thus, these all represent mechanisms by which a firm can access knowledge produced by another firm. As Cohen and Levinthal (1989) emphasized, presumably internal investments in knowledge are a prerequisite for absorbing such external knowledge even if it can be accessed.

A different research trajectory focused on flows of knowledge across firms where no market transaction or formal agreement occurred or what has become known as knowledge spillovers. The distinction between knowledge spillovers and technology transfer is that in the latter, a market transaction occurs, whereas in the case of spillovers, the benefits are accrued without an economic transaction (Acs and Varga 2005).

While Krugman (1991) and others certainly did not dispute the existence or importance of knowledge spillovers, they contested the claim that knowledge spillovers are geographically bounded. Their point was that when the marginal cost of transmitting information across geographic space approaches zero, there is no reason to think that the transmission of knowledge across geographic space will stop simply because it has reached the political border of a city, state, or country.

However, von Hippel (1994) explained how *knowledge* is distinct from *information* and requires geographic proximity in transmitting ideas that are highly dependent upon their context and inherently tacit and have a high degree of uncertainty. This followed from Arrow (1962), who distinguished economic knowledge from other economic factors as being inherently non-rival in nature so that knowledge developed for any particular application can easily spill over to generate economic value in very different applications. As Glaeser et al. (1992, p. 1126) have observed, "intellectual breakthroughs must cross hallways and streets more easily than oceans and continents."

Thus, a distinct research trajectory developed in the late 1980s and early 1990s, which tried to identify the impact of location on the innovative output of firms. These studies addressed the question "Holding firm-specific knowledge inputs constant, is the innovative output greater if the firm is located in a region with high investments in knowledge?" The answer to this question was provided in a series of studies, which shifted the unit of observation for testing the model of the knowledge production function from the firm to a spatial unit of observation, such as a city, region, or state. Furthermore, how does a region play a role in the public sector entrepreneurship and innovative capacity?

2.1.3 The Knowledge Filter

Because of the conditions inherent in radical innovation based on knowledge, high uncertainty, asymmetries, and transaction cost, decision-making hierarchies can decide not to commercialize new ideas that individual economic agents, or groups of economic agents, think are potentially valuable and should be pursued. The characteristics of knowledge that distinguish it from information include a high degree of uncertainty combined with nontrivial asymmetries, fused with a broad spectrum of institutions, rules, and regulations. These differences distinguish between radical innovation and incremental innovation. Thus, not all potential innovative activity, especially radical innovations, is fully appropriated within the firm, which made the investments to create that knowledge in the first place.

The ability of decision-makers to reach a consensus tends to be greater when it is based on more information and less knowledge, as information is easily transferable, put in context, and timely; therefore, it is more pertinent to decision-makers' incremental decisions. A decision's outcomes and their associated probability distributions are more certain when the decision is based on information and, by definition, less certain when it is based on knowledge, as knowledge is inherently more difficult to share and transfer. Radical innovation typically involves more knowledge and less information than does incremental innovation.

Various constraints on the ability of a large firm to determine the value of knowledge prevent the firm from fully exploiting the inherent value of its knowledge assets (Moran and Ghoshal 1999). In fact, evidence suggests that many large, established companies find it difficult to take advantage of all the opportunities emanating from their investment

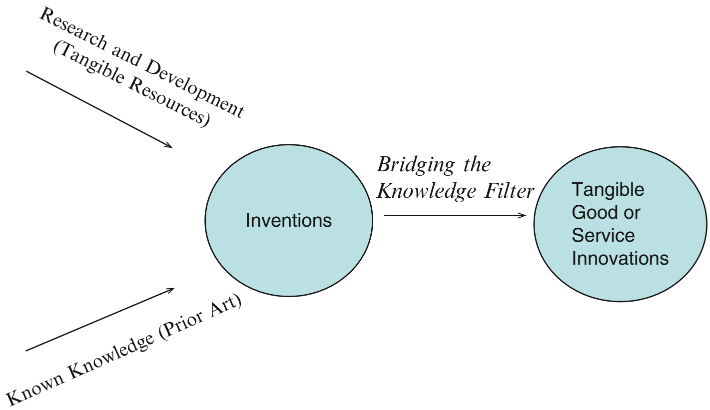

Fig. 2.1 The knowledge filter

in scientific knowledge (Christensen and Overdorf 2000). For example, Xerox's Palo Alto Research Center Incorporated succeeded in generating a large number of scientific breakthroughs (a superior personal computer, the facsimile machine, the Ethernet, and the laser printer, among others) yet failed to commercialize many of them and develop them into innovations (Smith and Alexander 1988; Chesbrough and Rosenbloom 2002). However, many incumbent firms have first-mover advantage, in that through their size and incremental innovation, they have the opportunity to acquire smaller firms, which tend to develop more radical innovations.

The knowledge conditions inherent in radical innovation impose what Audretsch et al. (2006a, b) and Acs et al. (2005) term *the knowledge filter* (see Fig. 2.1). The knowledge filter is the gap between knowledge that has potential commercial value and knowledge that is actually commercialized in the form of innovative activity. The greater the knowledge filter, the more pronounced the gap between new knowledge and commercialized knowledge in the form of innovative activity. An example of the knowledge filter which confronts a large firm is provided by the response of IBM to Bill Gates, who approached IBM to see if it was interested in purchasing the then struggling Microsoft. They weren't interested. IBM turned down "the chance to buy 10 % of Microsoft for a song in 1986, a missed opportunity that would cost $3 billion today."[2] IBM reached its decision on the grounds that "neither Gates nor any of his band of 30 some employees had anything approaching the credentials or personal characteristics required to work at IBM."[3]

Thus, the knowledge filter serves as a barrier impeding investments in new knowledge from being pursued and developed to generate innovative activity. In some cases, a firm will decide against developing and commercializing new ideas emanating from its knowledge investments even if an employee or group of

[2] "System Error," *The Economist,* 18 September 1993, p. 99

[3] Ibid.

employees think they have a positive expected value. As explained above, this divergence arises because of the inherent conditions of uncertainty, asymmetries, and high transaction costs, which created the knowledge filter. While Griliches' model of the knowledge production function focuses on the decision-making context of the firm concerning investments in new knowledge, Acs and Audretsch (1994), Audretsch (1995) proposed shifting the unit of analysis from the firm to the individual knowledge worker (or group of knowledge workers). This shifted the fundamental decision-making unit of observation in the model of the knowledge production function away from the exogenously assumed firms to individuals such as scientists, engineers, or other knowledge workers—agents with endowments of new economic knowledge. Shifting the focus away from the firm to the individual as the relevant unit of observation also shifts the appropriation problem to the individual so that the relevant question becomes how economic agents with a given endowment of new knowledge can best appropriate the returns from that knowledge. If an employee can pursue a new idea within the context of the organizational structure of the incumbent firm, there is no reason to leave the firm. If, on the other hand, employees place greater value on their ideas than the decision-making hierarchy of the incumbent firm, they may forgo what has been determined to be a good idea. Such divergences in the valuation of new ideas force workers to choose between forgoing ideas and starting a new firm to appropriate the value of their inherent knowledge.

Because radical innovative activity is based more on decisions involving knowledge and less on decisions involving information, it is accordingly more vulnerable to being impeded by the knowledge filter. By contrast, incremental innovation is based more on decisions involving information than knowledge and therefore is less vulnerable to being impeded by the knowledge filter.

By focusing on the decision-making context, which confronts the individual knowledge worker, the knowledge production function is actually reversed. Knowledge becomes exogenous and embodied in a worker. The firm is created endogenously in the workers' efforts to appropriate the value of their knowledge through innovative activity. Typically, an employee in an incumbent large corporation, often a scientist or engineer working in a research laboratory, will have an idea for an invention and ultimately for an innovation but will only act on the idea, or present it to the incumbent firm, if there is an expected return. Accompanying this potential innovation is an expected net return from the new product. The inventor would expect compensation for the potential innovation accordingly. If the company has a different, presumably lower, valuation of the potential innovation, the firm may decide either not to pursue its development or that it merits a lower level of compensation than that expected by the employee. In either case, employees will weigh the alternative of starting their own firm. If the gap in the expected return accruing from the potential innovation between the inventor and the corporate decision-maker is sufficiently large, and if the cost of starting a new firm is sufficiently low, the employee may decide to leave the large corporation and establish a new enterprise, such as the case with SAP.

The knowledge filter approach has important consequences concerning the role of policies. Particularly, Arrow (1962) identifies three types of market failure: those

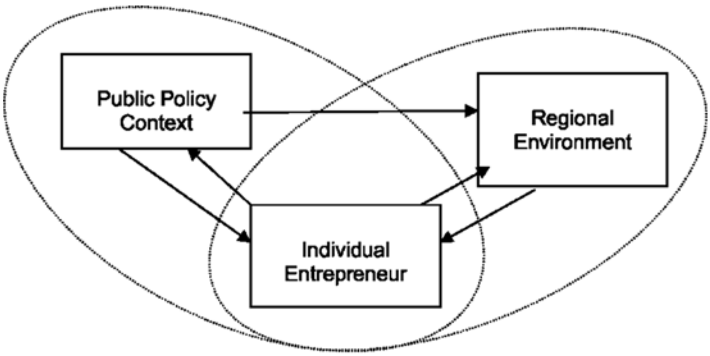

Fig. 2.2 The public policy/individual entrepreneur/regional environmental nexus. Source: Adapted from Feldman and Kelly 2001

associated with indivisibilities, inappropriability, and uncertainty. Public policies should try to correct for market failure associated with uncertainty, which demonstrates a problem with entrepreneurship. While in the classical knowledge production function approach, public policies are supposed to correct for failures in the market for the financing of innovation and for the positive externalities arising from the public good nature of R&D activities (which add to the stock of existing knowledge), according to the knowledge filter approach, public policies should also try to correct for the market failure associated with entrepreneurship Audretsch (2003) (see Fig. 2.2).

Such market failures might result in low levels of regional entrepreneurship capital that preempt scientists and other knowledge workers who perceive and recognize an entrepreneurial opportunity from actually pursuing that opportunity by starting a new firm and entering into entrepreneurship (not all regions, as a result of historical, institutional, and other reasons, are endowed with the same amount of entrepreneurial capital). Thus, public policies such as ATP and SBIR, but also regional and local policies, including science and technology parks and incubators, can serve to augment and enhance regional entrepreneurship capital, allowing companies, which require additional assets of capital, knowledge workers, or other missing ingredients, to develop their ideas into successful market innovations (more on this in Sect. 2.1.6).

Summarizing, when considering the different approaches, we have to recognize that each separate strand of literature focusing on technological innovation makes a distinct contribution to understanding the determinants of firm innovation. In particular, these different approaches to innovation suggest that four key units of observation are crucial in understanding the innovation process—the firm, the region, the individual, and the institutional/public policy context.

New-firm start-ups are important to innovation, because they embody a mechanism which facilitates the spillover of knowledge produced with one intended application in an incumbent corporation or university laboratory but which is actually commercialized by a new and different firm.

The individual matters to innovation because the individual scientists or engineers are confronted with a career trajectory decision—should they remain in a university laboratory or incumbent corporation or should they start a new high-technology enterprise? If no individual scientist or engineer makes the decision to start a new high-technology firm, there will be fewer spillovers and therefore less innovative activity, which will yield less economic activity.

Geography matters because the region provides the spatial platform in which knowledge spillovers are generated, absorbed, and ultimately commercially exploited and appropriated. A high density of high-technology firms, or highly skilled workers, forms a spatial cluster, where knowledge is more easily transferred between the similar groups of people over a small, clustered geographic space. The decision to start a new high-technology enterprise is shaped by the presence of knowledge and financial and other complementary assets that are available in the region.

2.1.4 Measuring and Identifying Innovative Firms

In order for an innovation agency to properly identify and award support to potential firms, a method of identifying innovation will be required. The section offers several different methods and concepts for identifying firms with potential market innovations.

2.1.4.1 Surveys and Expert Panels

One useful measurement technique for identifying innovations is the Community Innovation Survey (CIS). This survey is important in the EU context. Seven surveys were completed throughout Europe to understand how innovative specific fields were within the European context. Policy-makers and experts address needed improvements in innovative fields of technology use surveys to tailor their policy recommendations and responses.

There is also a long tradition of relying on industry experts to identify innovative activity. The first serious attempt to directly measure innovative output was by a panel of industry experts assembled by Gellman Research Associates (1976) for the National Science Foundation. The Gellman panel of international experts compiled a database of 500 major innovations that were introduced into the market between 1953 and 1973 in the United States, the United Kingdom, Japan, West Germany, France, and Canada. These innovations represented the "most significant new industrial products and processes, in terms of their technological importance and economic and social impact" (National Science Board 1975, p. 100).

A second and comparable database again involved an expert panel assembled by Gellman Research Associates (1982), this time for the US Small Business Administration. In this second study, Gellman compiled a total of 635 US innovations, including 45 from the earlier study for the National Science Foundation. The additional 590 innovations were selected from 14 industry trade journals for the

Table 2.1 Distribution of large- and small-form innovations according to significance levels (percentages in parentheses)

Innovation significance	Description	Number of innovations			
		Large firms		Small firms	
1	Establishes whole new categories	(0.00)	(0.00)	(0.00)	(0.00)
2	First of its type on the market in existing categories	50	(1.76)	30	(1.43)
3	A significant improvement in existing technology	360	(12.70)	216	(10.27)
4	Modest improvement designed to update existing products	2434	(85.53)	1959	(88.31)
Total		2834	(99.99)	2104	(100)

Source: Adapted from Acs and Audretsch (1990)

period 1970–1979. About 43 % of the sample was selected from the award winning innovations described in the *Industrial Research & Development* magazine.

The third data source that has attempted to directly measure innovation activity was compiled at the Science Policy Research Unit (SPRU) at the University of Sussex in the United Kingdom.[4] The SPRU data consist of a survey of 4378 innovations that were identified over a period of 15 years. The survey was compiled by writing to experts in each industry and asking them to identify "significant technical innovations that had been successfully commercialized in the United Kingdom since 1945, and to name the firm responsible" (Pavitt et al. 1987, p. 299).

Another study completed by Acs and Audretsch used 4938 innovations and an expert panel to apply four levels of significance (see Table 2.1): (1) innovation establishes an entirely new category of product; (2) innovation is the first of its type on the market for a product category already in existence; (3) the innovation represents a significant improvement in technology; and (4) the innovation is a modest improvement designed to update an existing product (Acs and Audretsch 1990).

Acs and Audretsch found that none of the innovations were at the highest significance level. However, they did find that small firms produced innovations which made up a considerable portion of the innovations within the field. There appeared to be little difference in the "quality" and significance of innovations between large and small firms.

The ex post approach of relying upon industry experts to distinguish between more and less significant innovations—that is, between radical and incremental innovations—has the advantage of being able to identify the extent to which a novel technological process is at the heart of the innovative process (Dewar and Dutton 1986). This approach is consistent with the view posited by Dutton and Thomas (1984) that technology is best defined in terms of the knowledge content.

[4] The SPRU innovation data are explained in considerable detail in Pavitt et al. (1987), Townsend et al. (1981), Robson and Townsend (1984), and Rothwell (1989).

2.1.4.2 Codified Innovation: Patents

In the past 20 years, patents have become one of the most common means of measuring the degree to which an innovation is incremental or radical. Patents have become an important metric in the innovation literature because of the easy and open paper trail provided by patent citations and applications. This trail clearly defines the origin of ideas and represents a clear trajectory of where ideas go when they are cited in the future. This trajectory comes in two forms: forward citations and backward citations. The patent citations also attribute a clear economic value to start-ups and economic growth (Trajtenberg 1990).

2.1.4.3 Forward Patent Citation Radicalness

Forward patent citation involves future citations of a patent. These citations come from the US patent examiners.[5] Rosenkopf and Nerkar (2001) measure the degree of radicalness of forward patent citations by examining the computer disk industry and investigate the impact patents have on future citations in different domains of patent classification. Patent domains are maintained and categorized by the US Patent and Trade Office (USPTO). The authors show how incremental patents are often more narrowly cited within a certain domain of patents, and multiple domains of patents often cite radical patents, i.e., outside of their original domain.

The forward patent count that Rosenkopf and Nerkar (2001) use is, in many ways, comparable to forward citations in scholarly journals. There are, however, two detrimental differences when using citations. First, it is in the interests of patent inventors to cite as little as possible from previous work. The less previous work is cited in the patent application, the more IP monopoly is granted to the inventor. Second, a patent examiner is required to assign relevant patent citations to the patent application. For a greater understanding of deficiencies in the US patent examining process, see Graham and Harhoff (2006) and Graham et al. (2002). Drawing on patent citations creates other problems as well. As Rosenkopf and Nerkar (2001, p. 290) define radical innovation: "'radical' exploration builds upon distant technology that resides outside of the firm. The technological subunit utilizes knowledge from a different technological domain and does not obtain that knowledge from other subunits within the firm."

The above definition of radicalness holds innovation exogenous to the human capital and tacit knowledge of the firm. As Klepper and Graddy (1990) show, however, new and radical innovations can also come from subunits within the firm. The distant technology can often be found within the incumbent firm, though it may be unwilling to operationalize the potential radical innovation due to managerial disagreements. It may also be unwilling to commit resources to a new and uncertain venture.

[5] These professionals cite the previous patent only when there is a legitimate reason to cite the previous patent's intellectual property.

2.1.4.4 Backward Patent Classification and Citations

Backward patent citations are citations given to prior work. Patent examiners cite previous patents and thereby give the citations, clear lines of intellectual property rights, and issue and examine these citations. Shane (2001) shows, through a unique data set from MIT inventors involving 1397 licensed MIT patents, that the more radical an invention is, the more likely it is to have been made by a small firm. Similarly, Acs and Audretsch (1990) find that small firms contribute a high share of innovations that could be classified as being more radical than incremental. These studies found that innovations emanating from small firms were more likely to be classified as radical than innovations from large firms. As Shane (2001, p. 208) explains, radical innovations tend to originate from newly established firms (typically small firms), whereas existing (and typically larger) firms have the competitive advantage in generating incremental innovations: "First, radical technologies destroy the capabilities of existing firms because they draw on new technical skills. Since organizational capabilities are difficult and costly to create (Nelson and Winter 1982; Hannan and Feeman, 1984), established firms are organized to exploit established technologies. Firms find it difficult to change their activities to exploit technologies based on different technical skills." Shane (2001) finds that research shows that radical patent citations and a lack of patent classification are positive to start-ups for the MIT-based patents. Joseph Schumpeter (1942) finds this *creative destruction* as an integral part of entrepreneurship and economic activity and growth.

2.1.5 Financing and Firm Size: How Small Firms Survive in Illiquid Capital Markets

One of the most consistent and compelling findings to emerge from a rich body of literature is that potential entrepreneurs with innovative ideas are frequently unable to attract adequate resources—financial, management, technical, and human capital—which impedes their ability to launch, sustain, or grow a new venture (Gompers and Lerner 2001). While this inability to attract resources has many names—financing constraints, liquidity constraints, or the infamous "valley of death" (Branscomb and Auerswald 2002)—all of them entail a high degree of uncertainty concerning the expected outcome valuation of a new idea, combined with asymmetries in information and knowledge.

Stiglitz and Weiss (1981) point out that, unlike most markets, the market for credit is exceptional in that the price of the good—the rate of interest—is not necessarily at a level that equilibrates the market. They attribute this to the fact that interest rates influence not only the demand for capital but also the risk inherent in different classes of borrowers. As the rate of interest rises, so does the risk of borrowing, leading suppliers of capital to rationally decide to limit the number and size of loans they make at any particular interest rate. The amount of information about an enterprise is generally not orthogonal to size. Rather, as Petersen and Rajan

(1994, p. 3) observe, "small and young firms are most likely to face this kind of credit rationing. Most potential lenders have little information on the managerial capabilities or investment opportunities of such firms and are unlikely to be able to screen out poor credit risks or to have control over a borrower's investments." If lenders are unable to identify the quality or risk associated with particular borrowers, credit rationing will occur and thereby create market failure (Burghof 2000). This phenomenon is analogous to the lemon argument put forth by George Akerlof (1970), where the market is unable to properly estimate the value of the start-up. This market failure leads entrepreneurs to bridge this "valley of death" in financing, team member employment, and advisor placement by other means than the commercial market clearinghouse for ideas.

The existence of asymmetric information prevents the suppliers of capital from engaging in price discrimination between riskier and less risky borrowers. But, as Diamond (1984) argues, the risk associated with any particular loan is also not neutral with respect to the duration of the relationship. This is because information about the underlying risk inherent in any particular customer is transmitted over time. With experience, a lender will condition the risk associated with any class of customers by characteristics associated with the individual customer.

Since potential entrepreneurs are left with the problem of how to finance, hire team members, and attract advisors for their entrepreneurial pursuits, other avenues of advancing their entrepreneurial interest must arise in the face of market failure. One potential answer may lie in their ability to create sufficient social capital with potential partners to overcome this market failure. If, for example, entrepreneurs are able to concentrate their efforts on interacting efficiently and quickly with a target group of investors, team members, or advisors, they may build enough social capital with the target group to form sufficient synergies for entrepreneurial success. Whether such concentrated efforts actually happen remains open to question by policy-makers and scholars due to the difficult nature of data collection.

Large incumbent firms with a proven track record can finance capital expenditures from their own internal resources, issuance of equity, or debt. By contrast, new entrepreneurial ventures have limited resources and are less able to issue equity. Since gathering information is costly, banks will expand their search for information until the expected marginal benefit of search equals zero. If the remaining information asymmetry induces a risk premium,[6] firms with fewer signaling opportunities will have higher costs of capital. The degree of information asymmetry depends on borrower characteristics such as firm size, firm age and governance, or legal form (Lehmann and Neuberger 2001). Typically, new and small firms provide less information to outside financiers than do their larger counterparts. This reflects the fixed costs of information disclosure or the absence of disclosure rules.

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[6] This compensation device has the drawback that rising loan rates aggravate moral hazard and adverse selection problems. Thus, the supply curve may bend backwards (Stiglitz and Weiss 1981). However, better information increases the ability to raise loan rates since the bank's loan offer curver is less likely to bend backwards.

In addition, lack of reputation constrains the borrowing capacity of new entrepreneurial firms (Martinelli 1997). As firms age, information asymmetries decrease, and firms may earn a positive reputation through a proven credit history. As a result, new entrepreneurial ventures are often associated with higher loan rates and less access to financial resources.

It would be erroneous to suggest that venture capital finances most of the early stage ventures in the United States. In fact, as Table 2.2 makes clear, most of the venture capital in the United States is focused instead on expansion and later-stage growth, rather than early stage ventures. A different source of funding for small business is provided by the Small Business Investment Companies (SBICs). The SBICs provide financing to small firms by making available equity capital, long-term loans, and management assistance to qualifying small businesses.

An important and broadly accepted strand of literature suggests that small and new firms will be at a competitive disadvantage with respect to generating innovative activity in general and radical innovations in particular. However, small and new firms whose goal is to be acquired by an incumbent know that they will only be acquired if they produce the best radical innovation. The success rate of smaller firms is correlated by their rate of innovation. According to Griliches' (1979) model of the knowledge production function, innovative activity is the direct result of a firm making investments in knowledge inputs, such as R&D and human capital. Since larger firms generally invest significantly more in R&D than small and new firms, they would be expected to generate more innovative activity. Since radical innovation generates more value than incremental innovation, some scholars have assumed, and even developed elaborate theoretical models to explain why, large firms, which have large R&D departments, will generate more radical innovations than small and new firms, which are constrained by size in their ability to invest in R&D (Cohen and Klepper 1992a, b). Others, however, argue that incumbent firms will only have an incentive to invest in radical innovation if they can assure that they will produce the best and second-best radical innovation (Henkel et al. 2015).

Five factors favoring the innovative advantage of large enterprises have been identified in the literature. First is the argument that innovative activity requires a high fixed cost. As Comanor (1967) observes, R&D typically involves a "lumpy" process that yields scale economies. Similarly, Galbraith (1956, p. 87) argues, "Because development is costly, it follows that it can be carried on only by a firm that has the resources which are associated with considerable size." Second, only firms that are large enough to attain at least temporary market power will choose innovation as a means for maximization (Kamien and Schwartz 1975). This is because the ability of firms to appropriate the economic returns accruing from R&D and other knowledge-generating investments is directly related to the extent of that enterprise's market power (Levin et al. 1985, 1987; Cohen et al. 1987; Cohen and Klepper 1991). Third, R&D is a risky investment; small firms engaging in R&D make themselves vulnerable by investing a large proportion of their resources in a single project. However, their larger counterparts can reduce the risk accompanying innovation through diversification into simultaneous research projects. The larger firm is also more likely to find an economic application for the

Table 2.2 The US venture capital investment, financing stage, industry, and number of companies: 1995–2008 (millions of current dollars)

Financing stage/industry/ number of companies	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
All financing stages	**7628**	**10,840**	**14,364**	**20,172**	**52,016**	**101,767**	**39,308**	**21,250**	**19,278**	**22,117**	**22,922**	**26,334**	**30,639**	**28,077**
Seed/start-up	1244	1267	1309	1679	3571	3053	739	327	341	461	893	1194	1330	1494
Early	1694	2614	3430	5389	11,263	24,569	8387	3723	3455	3918	3830	4195	5686	5346
Expansion	3553	5340	7382	9999	28,720	58,138	22,248	12,063	9760	9086	8574	11,417	11,386	10,473
Later	1138	1619	2243	3105	8463	16,007	7935	5138	5723	8653	9626	9528	12,237	10,765
All industries	**7628**	**10,840**	**14,364**	**20,172**	**52,016**	**101,767**	**39,308**	**21,250**	**19,278**	**22,117**	**22,922**	**26,334**	**30,639**	**28,077**
Biotechnology	768	1156	1385	1520	2029	4057	3400	3183	3553	4145	3924	4504	5247	4410
Business products and services	177	377	409	691	2791	4560	1031	450	579	396	396	552	709	477
Computers and peripherals	324	383	377	372	897	1596	655	457	373	590	539	532	586	424
Consumer products and services	473	503	738	622	2534	3350	662	228	163	309	304	407	476	437
Electronics/instrumentation	125	193	260	227	282	773	381	314	236	351	438	722	563	574
Financial services	194	329	362	781	2202	4180	1380	338	410	520	918	462	558	526
Healthcare services	448	664	869	926	1368	1352	499	368	222	363	407	381	295	192
Industrial/energy	529	504	696	1407	1508	2479	1067	740	756	775	808	1925	3222	4576
Information technology services	178	430	655	1057	3958	8619	2391	1039	775	737	1063	1377	1707	1812
Media and entertainment	910	1074	956	1744	6560	10,299	2312	712	879	965	1149	1624	1962	1884
Medical devices and equipment	627	648	1016	1144	1511	2312	1997	1838	1602	1921	2186	2910	3872	3446

Networking and equipment	347	612	937	1360	4259	11,409	5543	2595	1737	1545	1517	1091	1378	735
Other	10	21	56	88	84	45	62	4	0	1	57	8	2	23
Retailing/distribution	314	257	303	609	2805	3067	321	151	65	174	207	201	365	235
Semiconductors	202	299	567	618	1290	3542	2391	1503	1764	2128	1923	2101	2080	1641
Software	1123	2218	3281	4367	10,295	24,012	10,141	5150	4462	5375	4803	4920	5423	5027
Telecommunications	880	1171	1498	2639	7642	16,116	5074	2180	1701	1822	2283	2618	2196	1659
Internet specific	505	1562	2359	4457	23,331	42,233	9848	3577	2388	2875	3336	4336	5176	4871
Clean technology	77	157	144	107	200	577	386	390	263	440	523	1458	2656	4023
Number of companies	**1539**	**2076**	**2537**	**2979**	**4404**	**6335**	**3786**	**2634**	**2461**	**2625**	**2708**	**3089**	**3301**	**3262**

Notes: The *seed/start-up* stage includes proof of concept (seed), research, product development, or initial marketing. *Early* includes financing for activities such as initial expansion, commercial manufacturing, and marketing. *Expansion* includes major expansion of activities or to prepare a company expecting to go public within 6–12 months. *Later* includes acquisition financing and management and leveraged buyout. *Internet specific* are companies whose business model is fundamentally dependent on the Internet, regardless of the company's primary industry category. *Clean technology* comprises companies that focus on alternative energy, pollution and recycling, power supplies, and conservation

Source: Adapted from National Science Board, *Science and Engineering Indicators 2010*

uncertain outcomes resulting from innovative activity (Nelson 1959). Fourth, scale economies in production may also provide scope economies for R&D. Scherer (1991) notes that economies of scale in promotion and distribution facilitate penetration of new products, enabling larger firms to enjoy greater profit potential from innovation. Finally, an innovation yielding cost reductions of a given percentage results in higher profit margins for larger firms than for smaller firms. There is also substantial evidence that technological change—or rather one aspect of technological change, R&D—is, in fact, positively related to firm size.

The empirical evidence from a plethora of studies suggests that, in terms of R&D inputs, large and more mature firms tend to make greater investments (i.e., R&D expenditures in absolute values) than do their smaller and younger counterparts. However, in terms of innovative outputs, the empirical evidence is very different. Younger and smaller enterprises contribute considerably more to innovative output than they do to R&D inputs and therefore account for a greater share of innovative activity than they do for R&D investments (Acs and Audretsch 2010). Moreover, as previously mentioned, newly established and small firms tend to generate more radical innovations, while established (and larger) firms focus more on incremental innovations.

2.1.6 Role of Public Support Programs in Reducing Market Failures in Financing of Small (and Young) Companies

The most predominant theory of innovation assumes that innovative opportunities are the result of systematic efforts by firms and the result of purposeful efforts to create knowledge and new ideas and subsequently to appropriate the returns on those investments through their commercialization (Chandler 1990; Cohen and Levinthal 1989; and Griliches 1979).

In what Griliches formalized as the model of the knowledge production function, (exogenously existing) firms (endogenously) create innovative output through purposeful and dedicated investments in new knowledge (R&D and human capital, for instance, through training and education). In this framework, an important point for thinking about (and also analyzing and evaluating the impact of) public policy on innovation is through focusing on the unit of observation of the firm. How does the firm change its activities, behavior, strategies, and output as a result of policy intervention? For example, can policy tools, such as the National Science Foundation funded research, help existing firms in generating new sources of knowledge? Moreover, are there specific policy institutions, such as the STTR, that can help facilitate these knowledge spillovers? Certainly, a minor army of scholars have put together a formidable body of literature which analyzes and evaluates the impact of various public policy instruments, including but not limited to the ATP and SBIR, on the innovative and economic performance of the firm (Branscomb and Auerswald 2002; Feldman and Kelley 2000, 2001; Powell and Lellock 1997; Silber and Associates 1996).

A stark contrast to this focus on the firm is provided by the intellectual tradition in entrepreneurship literature, where the focus is on the cognitive decision-making process of the individual to start a new firm and enter into entrepreneurship.

There is virtual consensus in the entrepreneurship literature that entrepreneurship revolves around the recognition of opportunities and the pursuit of those opportunities (Venkatraman 1997). But the existence of those opportunities is, in fact, taken as given. The focus has been on the cognitive process by which individuals reach the decision to start a new firm. This has resulted in a methodology focusing on differences across individuals in analyzing the entrepreneurial decision (Stevenson and Jarillo 1990). Krueger (2003, p. 105) has pointed out that, "The heart of entrepreneurship is an orientation toward seeing opportunities," which frames the research questions, "What is the nature of entrepreneurial thinking and what cognitive phenomena are associated with seeing and acting on opportunities?"

Thus, the traditional approach to entrepreneurship essentially holds the opportunities constant and then asks how the cognitive process inherent in the entrepreneurial decision varies across different individual characteristics and attributes (Carter et al. 2003; McClelland 1967). Eckhardt and Shane (2003, p 187) summarize this literature in introducing the individual-opportunity nexus (see Fig. 2.2): "We discussed the process of opportunity discovery and explained why some actors are more likely to discover a given opportunity than others." Some of these differences involve the willingness to incur risk; others involve the preference for autonomy and self-direction, while still others involve differential access to scarce and expensive resources, such as financial capital, human capital, social capital, and experiential capital.

The two approaches, the one focusing on existing firms and the other pointing to entrepreneurship, identify different sources for knowledge spillovers and market failures, and this generates different policy prescriptions. For instance, while Romer (1986), Lucas (1993), and others assumed that knowledge spillovers would automatically serve as the engine for innovation and economic activity and growth, Acs et al. (2005) and Audretsch et al. (2006a, b) suggest that the "knowledge filter" may actually impede the spillover and commercialization of knowledge. To the degree that the knowledge filter impedes or constrains the spillover and commercialization of knowledge, entrepreneurship can serve as the missing link to economic growth by providing a conduit for the spillover of knowledge that might otherwise never have been commercialized (Audretsch et al. 2006a, b). This could explain why, for example, in the European Union, we observe the simultaneous existence of high investments in new knowledge in the form of research and development (R&D), university research, and high levels of human capital, combined with stagnant rates of economic growth and high levels of unemployment (so-called European paradox). In fact, empirical evidence suggests that regions endowed with higher levels of entrepreneurship capital also exhibit stronger economic performance, suggesting that new-firm start-ups serve as an important conduit for knowledge spillovers and commercialization. Thus, public policies such as ATP and SBIR, and also regional and local policies, including science and technology parks and incubators, can serve to augment and enhance regional entrepreneurial capital. Indeed, as illustrated in Fig. 2.3, government programs can assist firms in their technology creation and technological development of their ideas.

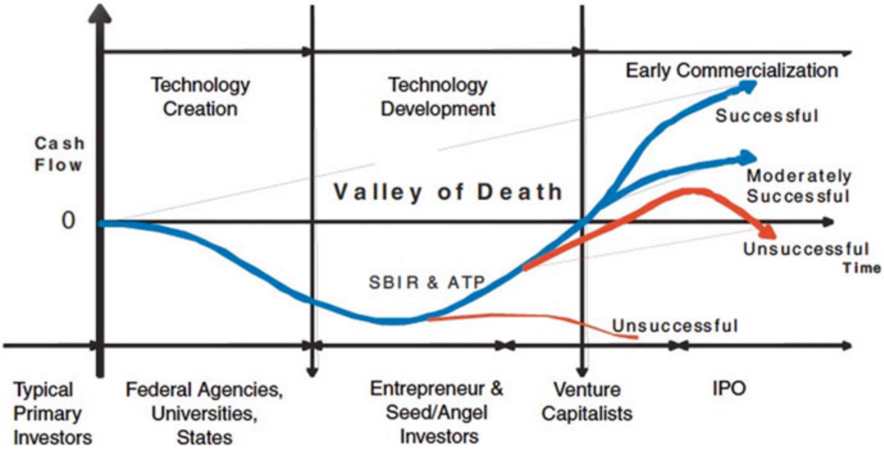

Fig. 2.3 The valley of death. Source: Adapted from Wessner, *An Assessment of the SBIR Program*, p. 30

This governmental assistance affords companies, which require additional assets of capital, knowledge workers, or other missing ingredients, the opportunity to develop their ideas into successful market innovations.

Innovative performance in the United States has been shaped by public policy. Examples of public policy instruments, which influence American innovative performance, range from immigration laws and enforcement to the R&D tax credit, Small Business Innovation Research (SBIR) program, and the Bayh-Dole Act. These instruments influence the ability of universities and university scientists to commercialize their research and ideas.

Immigration policy generally influences the supply of human capital, and particularly, the supply of scientists and engineers. The Hart-Cellar Act[7] established the basic immigration policy in the United States. High-skilled workers, including scientists and engineers, are permitted to enter into the United States and therefore become legally eligible for employment by high-technology companies, through the H-1, L-1, O-1, and TN visa categories. Under the H-1B visa, which is the most common, the foreign scientist may retain legal residence for a period of 3 years, which can be extended for up to 6 years. The L-1 visa applies to the intercompany transfer of international employees for employment in the United States by the same company. The O-1 visa is applicable for individuals with extraordinary ability. Immigrant visas, which are commonly referred to as the green card, are restricted to 145,000 annually. An E-2 visa enables an individual to enter and work inside the United States if he finances the start-up of a new firm. An EB-5 visa applies to foreigners creating or preserving at least ten jobs for US workers.[8]

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[7] See: http://library.uwb.edu/guides/usimmigration/79%20stat%20911.pdf.

[8] See: http://www.uscis.gov/USCIS/About%20Us/Electronic%Reading%20Room/Customer%20Service%20Reference%20Guide/Nonimmigrant_Empl.pdf

Another important policy instrument, which facilitates innovation in the United States, is the R&D tax credit. In 1981, the US Congress passed a new law authorizing a tax credit for companies investing in R&D. The tax credit stipulated a 25 % credit for R&D expenditures in excess of the average of a firm's R&D expenditure in a base period (generally, the previous 3 taxable years). Congress has renewed the R&D tax credit in subsequent years. Most OECD countries have also adopted the R&D tax credit in some form or another. While there were 12 OECD countries providing an R&D tax credit in 1996, by 2008, the number had grown to 21. Most states within the United States also have R&D tax credits or a similar measure to promote R&D investments at the state or local level.

While immigration policy and the R&D tax credit enhance investments in the innovative process, other instruments are designed to effectively penetrate the knowledge filter. In particular, the Bayh-Dole Act was enacted to facilitate the commercialization of research that might otherwise remain dormant and undeveloped for innovative activity in the laboratories of universities. Prior to the Bayh-Dole Act, the bureaucratic impediments of interacting between potential innovators and the governmental agencies seem to reduce the commercialization of many scientific projects at universities. The Bayh-Dole Act effectively transferred the property rights of federally financed research and scientific projects from the funding government agency to the university. This made the university responsible for deciding how best to manage the process of commercializing scientific knowledge and transforming it into innovative activity, rather than the funding government agency. Thus, the contemporary policy in the United States is clearly oriented toward penetrating the knowledge filter impeding the spillover of ideas created at universities into innovative activity.

A second example of innovation policy in the United States designed to facilitate penetration of the knowledge filter involves the Small Business Innovation Research (SBIR) program. As discussed in the previous sections, many nascent entrepreneurs and small firms are unable to procure sufficient funding to facilitate early stage finance of innovative ventures. The SBIR was created to provide such early stage funding and enable firms to cross what has become known as the "valley of death" or the financing constraints, which typically confront new and young firms, especially in knowledge-based and high-technology industries. As a result of the introduction of the SBIR, and its subsequent effect on American innovative activity, a plethora of states, cities, and regions have implemented more local policies designed to enable small and young firms to develop proposals for SBIR funding. As the next section will make clear, the SBIR has had a strong and positive impact on the innovative performance of the United States.

2.1.7 The Small Business Innovation Research Program (SBIR)

In the United States, the 1970s was characterized by sluggish growth, persistent high rates of unemployment, and inadequate rates of job creation. In response to these economic problems, the US Congress enacted the Small Business Innovation

Research (SBIR) program in 1982 explicitly to reinvigorate jobs and growth by enhancing the innovative capabilities of the United States. In particular, the mandate assigned by the Congress was to explicitly (1) promote technological innovation, (2) enhance the commercialization of new ideas emanating from scientific research, (3) increase the role of small business in meeting the needs of federal research and development, and (4) expand the involvement of minority and disadvantaged people in innovative activity.

The SBIR program functions through the 11 federal agencies,[9] which administer the program and award around $2.5 billion annually for innovative activity by small business. Qualifying small businesses are eligible to apply to the participating federal agencies of up to $150,000 for a Phase I award over a 6-month period. The Phase I objective for funding is to "establish technical merit, feasibility and commercial potential of the proposed R&D efforts to determine the quality of performance of the small business awardee organization"[10] prior to Phase II funding. Phase II funding is dependent on Phase I funding. Only Phase I awardees may apply for Phase II funding. If the results of the Phase I awardee clearly show scientific and technical merit, the Phase II funding awards an amount of up to $1,000,000 over a 2-year period. Phase III funding is more of a business construct where the SBIR no longer funds the business, and the small businesses must find funding in the private sector or other non-SBIR federal agency funding. To commercialize their product, small businesses are expected to garner additional funds from private investors, the capital markets, or from the agency that made the initial award.[11] In Fig. 2.4, the entire timeline from Phase I to Phase III and the time allocated to each phase are shown.

University scholars have analyzed the impact of the SBIR program in considerable detail in a series of meticulous studies undertaken by the Board on Science, Technology, and Economic Policy of the National Research Council of the National Academy of Sciences and also in a number of important studies (Fig. 2.5). There is compelling empirical evidence that the SBIR has generated a number of substantial benefits to the US economy. The country is no doubt more innovative and more competitive in the global economy and has generated more and better jobs as a result of SBIR. The studies assessing the impact of the SBIR program have generated robust findings. Studies with disparate methodologies, including case studies

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[9] The agencies consist of the Department of Agriculture, Department of Commerce (National Institute of Standards and Technology and National Oceanic and Atmospheric Administration), Department of Defense, Department of Education, Department of Energy, Department of Health and Human Services, Department of Homeland Security, Department of Transportation, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation.

[10] http://www.sbir.gov/faq/sbir#t25n66932

[11] National Research Council (US) Committee on Capitalizing on Science, Technology, and Innovation; Wessner CW, editor. SBIR and the Phase III Challenge of Commercialization: Report of a Symposium. Washington (DC): National Academies Press (US); 2007. I, Introduction: SBIR and the Phase III Challenge of Commercialization. Available from: http://www.ncbi.nlm.nih.gov/books/NBK11392/

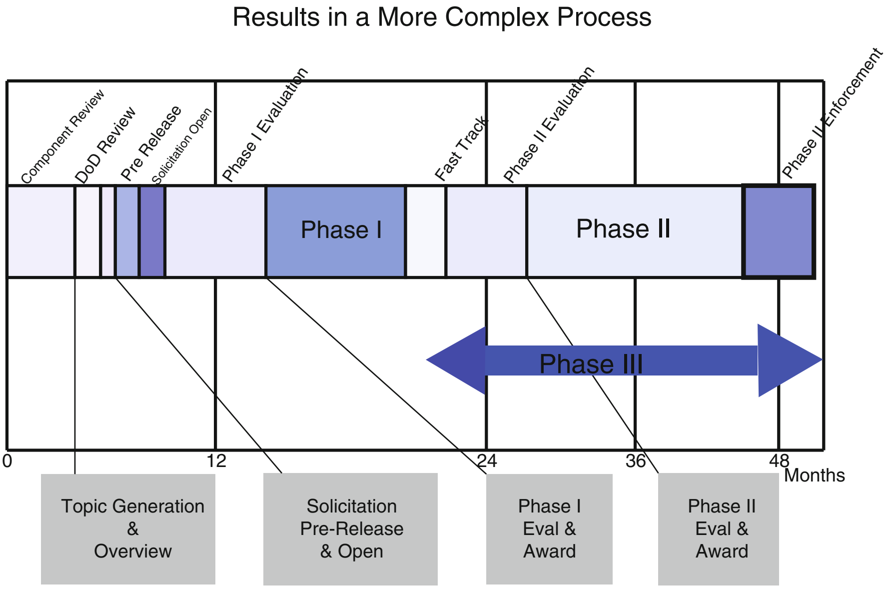

Fig. 2.4 The SBIR timeline

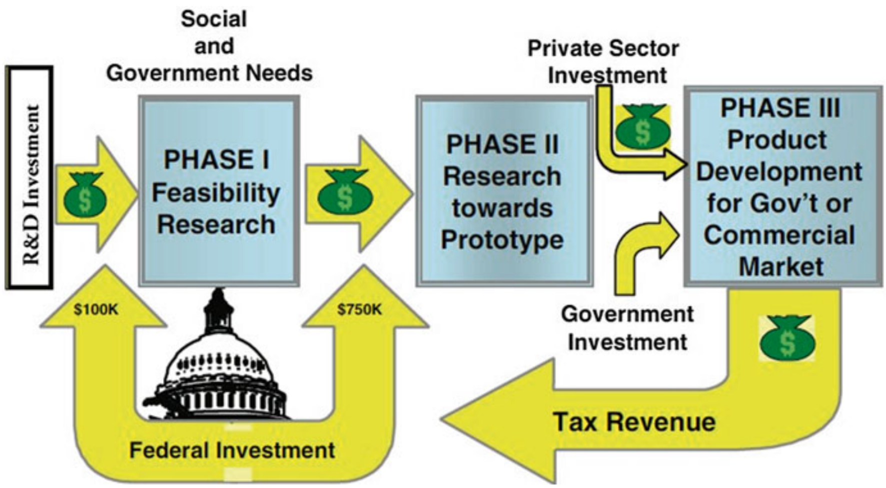

Fig. 2.5 The structure of the SBIR program. Source: Adapted from Wessner, *An Assessment of the SBIR Program*, p. 23

of recipient firms, interviews with program administrators at the funding agencies, systematic analyses of broad-based surveys of firms, and sophisticated econometric studies based on objective measures comparing the performance of recipient SBIR firms with control groups consisting of matched pairs that did not receive any SBIR support, all point to the same thing—the SBIR has made a key and unequivocal contribution to the innovative performance of the United States, especially in terms of technological innovation.

In particular, a number of key benefits emanating from the SBIR program can be identified from the literature. The key economic benefits accruing from implementation of the SBIR program are most compelling in terms of two of the objectives stated in the Congressional mandate—the promotion of technological innovation and increased commercialization from investments in research and development.

There is strong and compelling evidence that the United States is considerably more innovative as a result of the SBIR program than it would be without it.

- **Recipient SBIR firms are more innovative**: Existing small businesses are more innovative as a result of the SBIR program. A painstaking study undertaken by the National Research Council of the National Academy of Sciences found that around two thirds of the projects would not have been undertaken had they not received SBIR funding.[12] The same study also identified a remarkably high rate of innovative activity emanating from the SBIR-funded projects. Slightly less than half of the SBIR-funded projects actually resulted in an innovation in the form of a new product or service that was introduced into the market. Such a high rate of innovative success is striking given the inherently early stage and high-risk nature of the funded projects. A thorough review and summary of the empirical evidence testing the systematic impacts of the SBIR have concluded that (Audretsch 2010).
- **The SBIR has generated more technology-based start-ups**: The SBIR program results in a greater number of technology-based firms. One key study found that over one fifth of all recipient SBIR companies would not have existed in the absence of an SBIR award.
- **Recipient SBIR firms have stronger growth performance**: Studies consistently find that firms receiving SBIR awards exhibit higher growth rates than do control groups of matched pair companies.
- **Recipient SBIR firms are more likely to survive**: The early phase for technology entrepreneurial ventures has been characterized as *the valley of death*. The empirical evidence suggests that the likelihood of survival for young technology-based SBIR recipients is greater than for comparable companies in carefully selected control groups.
- **The SBIR has resulted in greater commercialization of university-based research**: Empirical evidence points to a high involvement of universities in SBIR-funded projects. One or more founders have been employed at a university in two thirds of the SBIR recipient firms. More than one quarter of the SBIR-funded projects involved contractors from university faculties.
- **The SBIR has increased the number of university entrepreneurs**: Studies find that scientists and engineers from universities have become entrepreneurs and started new companies, who otherwise might never have done so. Some of these university-based entrepreneurs are involved in firms that have received SBIR awards. Others have been inspired to become entrepreneurs as a result of learning about the efficacy

[12] National Research Council, *An Assessment of the SBIR Program.* C. Wessner (ed.), Washington, D.C.: National Academies Press, 2008.

of becoming an entrepreneur from the observed success and experiences of their colleagues who have been involved with SBIR-funded companies.

Despite the compelling evidence of the strong and significant impact that the SBIR program has contributed to promoting innovation in the United States, are also a number of important qualifications and concerns about the impact of the SBIR. An important study by Gans and Stern (2003) found that many of the projects receiving SBIR funding would have been undertaken even in the absence of SBIR support. Their results cast at least some doubt that the SBIR generates innovative activity that otherwise would not have been undertaken. Similarly, a study by Lerner (1996, 2002) concludes that, while firms receiving support from the SBIR do exhibit higher rates of growth, having multiple awards does not contribute to higher firm growth rates. In addition, Wallsten (2000) concludes that firms receiving SBIR support do not significantly increase their investments in R&D and innovative activity. Other concerns have been expressed concerning the strong geographic concentration of the SBIR awards and the relatively low participation rates of females and minorities in procuring SBIR awards (Audretsch 2010).

Some agencies, such as the Department of Defense and NASA, select potential awardees on desired emerging potential technologies, while other agencies such as NIH and HHS select awards based on potential returns to society. SBIR and most public funds emphasize the importance of early stage financing, which is generally ignored by private venture capital. Some of the most innovative American companies received early stage financing from SBIR, including Apple Computer, Chiron, Compaq, and Intel.

The design of the SBIR program is as follows[13]:

2.1.7.1 Phase I

Federal agencies solicit contract proposals or applications for feasibility-related research with either general or narrow requirements as determined by the needs of that agency. Proposals are competitively evaluated on scientific and technical merit and feasibility, potential for commercialization, program balance, and agency requirements, and may require a Phase II proposal as a deliverable. Awarded efforts are further evaluated before consideration for Phase II funding. Agencies may select to fund multiple proposals for a given project or need.

2.1.7.2 Phase II

Phase II funding is awarded to selected Phase I-funded projects based on merit and commercial potential so that they can continue R/R&D efforts. Examples of commercial potential include a record of successful commercialization, private sector funding commitments, and Phase III follow-on commitments.

[13] See: http://www.sbir.gov/faq/sbir#t25n66932

2.1.7.3 Phase III

Projects resulting from or concluding prior SBIR-funded efforts but that are funded by sources outside of the SBIR program may receive a Phase III award for commercialization of the resulting products, productions, services, research, and research and development.

In 2009, the SBIR program was budgeted more than $2.5 billion. The SBIR consists of the following three phases: Phase I is oriented toward determining the scientific and technical merit along with the feasibility of a proposed research idea. The award is for 6 months and cannot exceed $150,000. Phase II extends the technological idea and emphasizes commercialization. A Phase II award is awarded to the most promising of the Phase I projects based on scientific and technical merit, the expected value to the funding agency, company capability, and commercial potential. The award is for a maximum of 24 months and generally does not exceed $1,000,000. Phase I awards accounted for $47 million, Phase II, $194 million.[14]

As shown in Table 2.3, approximately 40 % of Phase I awards continue on to Phase II. Phase III involves additional private funding in various forms for the commercial application of a technology. Taken together, public SME funding is about two thirds as large as private venture capital, and the SBIR represents about 60 % of all public small- and medium-sized enterprise (SME) finance programs. In 1995, the sum of equity financing provided through and guaranteed by SME programs was $2.5 billion, which amounted to more than 60 % of the total money disbursed by traditional venture funds that year. Through the SBIR program, the National Institutes of Health (NIH) awarded $266 million to small firms for medical and biopharmaceutical research. As shown in Table 2.4, over $20.8 billion was disseminated to 11 different agencies from 1983 to 2006.

2.1.7.4 Selection Process of Wining Project and Criteria Needed to Select Awardees

The process for the selection of awardees is straightforward. From the time a solicitation is published on agency websites,[15] applicants generally have 2 months to apply. Awardees are selected on the basis of merit, which is determined by a panel of experts. This panel is generally a mix of agency experts and experts from outside of the government, who come from both the for-profit and nonprofit sectors. After submission, the respective agency generally takes 6 months to select awardees. The preconditions to apply for a Phase I funding are as follows:

[14] The US Department of Defense also uses the SBIR program to fund firms, awarding more than $10,253 billion between 1983 and 2006.

[15] Coordination for all SBIR calls can be found on the US website https://www.fbo.gov/. This website is very similar to its European counterpart: ted.europa.eu/TED/main/HomePage.do All calls can also be found on the respective agency home pages with clear instructions on what a particular agency is currently interested in funding and how to apply.

Table 2.3 SBIR awards, by award phase: FY 1983–2006

SBIR			
Fiscal year	Phase I	Phase II	Total
1983	686	0	686
1984	999	338	1337
1985	1397	407	1804
1986	1945	564	2509
1987	2189	768	2957
1988	2013	711	2724
1989	2137	749	2886
1990	2346	837	3183
1991	2553	788	3341
1992	2559	916	3475
1993	2898	1141	4039
1994	3102	928	4030
1995	3085	1263	4348
1996	2841	1191	4032
1997	3371	1404	4775
1998	3022	1320	4342
1999	3334	1256	4590
2000	3166	1330	4496
2001	3215	1533	4748
2002	4243	1577	5820
2003	4465	1759	6224
2004	4638	2013	6651
2005	4300	1871	6171
2006	3835	2026	5861
Total	68,339	26,690	95,029

Source: Adapted from National Science Board, *Science and Engineering Indicators 2010*

1. The awardee must be a for-profit organization based in the United States with no more than 500 employees.
2. At least 51 % of the company must be US-based and for profit.
3. For-profit firms may not have direct investment with other foreign countries.
4. Generally, no more than three SBIR applications may be submitted at one time.
5. The proposal must, as in the case of NASA, "clearly and concisely (1) describe the proposed innovation relative to the state of the art; (2) address the scientific, technical and commercial merit and feasibility of the proposed innovation, and its relevance and significance to NASA's needs as described in Sect. 2.1.9: and (3) provide a preliminary strategy that addresses key technical, market and business factors pertinent to the successful development, demonstration of the proposed innovation, and its transition into products and services for NASA mission programs and other potential customers."[16]

[16] http://sbir.gsfc.nasa.gov/SBIR/sbirselect2012/solicitation/chapter3.html

Table 2.4 SBIR award funding, by type of award and federal agency: FY 1983–2006 (in millions of current dollars)

Year	All	Phase I	Phase II	DOD	HHS	NASA	DOE	NSF	DHS[a]	USDA	DOT	EPA	ED	DOC
1983	44.5	44.5	0.0	20	7	5	5	5	NA	1	*	*	*	0
1984	108.4	48.0	60.4	45	23	13	16	7	NA	2	2	1	1	0
1985	199.1	69.1	130.0	78	45	29	26	10	NA	3	3	2	1	0
1986	297.9	98.5	199.4	151	57	36	29	15	NA	4	4	3	2	1
1987	350.5	109.6	240.9	194	67	32	28	17	NA	4	3	3	2	2
1988	389.1	101.9	248.9	208	73	47	30	17	NA	4	3	3	2	1
1989	431.9	107.7	321.7	233	79	52	33	19	NA	4	4	3	2	1
1990	460.7	118.1	341.8	241	84	62	39	20	NA	4	4	3	2	1
1991	483.1	127.9	335.9	241	93	69	39	22	NA	5	6	4	3	1
1992	508.4	127.9	371.2	242	102	79	43	23	NA	6	3	4	2	2
1993	698.0	154.0	490.7	385	126	86	50	29	NA	7	4	5	3	2
1994	717.6	220.4	473.6	354	133	116	53	34	NA	7	7	5	3	4
1995	834.5	232.2	601.9	414	181	118	70	42	NA	9	10	7	3	8
1996	916.3	228.9	645.8	479	189	114	62	41	NA	9	7	5	3	6
1997	1106.9	277.6	789.1	569	252	121	75	54	NA	10	8	6	4	7
1998	1066.7	262.3	804.4	540	267	96	76	53	NA	13	6	5	5	7
1999	1096.5	299.5	797.0	514	314	89	81	60	NA	13	6	5	5	7
2000	1190.2	302.0	888.2	549	355	93	86	65	NA	15	6	8	6	7

2001	1294.3	317.0	977.3	576	412	106	87	72	NA	16	6	6	7	7
2002	1434.7	411.4	1023.3	621	487	110	96	78	NA	17	6	6	8	7
2003	1670.3	455.3	1215.0	804	531	109	94	90	NA	17	3	6	8	8
2004	1867.6	498.8	1368.8	929	572	106	104	90	19	19	4	8	9	9
2005	1865.9	461.2	1404.7	926	580	113	100	79	22	19	4	6	8	9
2006	1883.2	411.2	1472.0	940	573	104	104	90	30	17	3	6	9	7
Total	20916.3	5485.0	15202.0	10253.0	5602.0	1905.0	1426.0	1032.0	71.0	225.0	112.0	110.0	98.0	104.0

Notes: Agency obligations based on information from Small Business Administration (SBA). Data do not necessarily contain subsequent-year revisions and may not add to total

NA = not available; * = ≤$500,000

DHS Department of Homeland Security, *DOC* Department of Commerce, *DOD* Department of Defense, *DOE* Department of Energy, *DOT* Department of Transportation, *ED* Department of Education, *EPA* Environmental Protection Agency, *HHS* Department of Health and Human Services, *NASA* National Aeronautics and Space Administration, *NSF* National Science Foundation, *SBIR* Small Business Innovation Research program, *USDA* US Department of Agriculture

[a]DHS, established by Homeland Security Act of 2002 and formed in January 2003, held the first SBIR competition in FY 2004

Source: Adapted from National Science Board, *Science and Engineering Indicators 2010*

The purpose of these conditions is simply to ensure that the resources dedicated to the awardee will remain in the United States and consequently benefit the US economy. Another aspect of the award is that most agencies attempt to select awardees where they feel a need for prospective innovations in their respective fields. Most agencies offer some sort of open evaluation checklist for applicants to consider, when they apply for an award. As shown in Table 2.5, one can clearly see how, in this case, the NIH weights its evaluations:

Table 2.5 Evaluation criteria for Phase I and II NIH awardees

In considering the technical merit of each proposal, the following factors will be assessed: *Factors for Phase I proposals*	*Weight (%)*
1. The soundness and technical merit of the proposed approach and identification of clear measurable goals (milestones) to be achieved during Phase I. (Preliminary data are not required for Phase I proposals.)	40
2. The qualifications of the proposed PDs/PIs, supporting staff, and consultants. For proposals designating multiple PDs/PIs is the leadership approach, including the designated roles and responsibilities, governance, and organizational structure, consistent with and justified by the aims of the project and the expertise of each of the PDs/PIs?	20
3. The potential of the proposed research for technological innovation	15
4. The potential of the proposed research for commercial application. The commercial potential of a proposal will be assessed using the following criteria: (a) Whether the outcome of the proposed research activity will likely lead to a marketable product or process (b) The offeror's discussion of the potential barriers to entry and the competitive market landscape	15
5. The adequacy and suitability of the facilities and research environment	10
Factors for Phase II proposals	*Weight (%)*
1. The scientific/technical merit of the proposed research, including adequacy of the approach and methodology, and identification of clear, measurable goals to be achieved during Phase II	30
2. The potential of the proposed research for commercialization, as documented in the offeror's commercialization plan and evidenced by (a) the offeror's record of successfully commercializing its prior SBIR/STTR or other research projects, (b) commitments of additional investment during Phase II and Phase III from private sector or other non-SBIR funding sources, and (c) any other indicators of commercial potential for the proposed research	30
3. The qualifications of the proposed PDs/PIs, supporting staff and consultants. For proposals designating multiple PDs/PIs is the leadership approach, including the designated roles and responsibilities, governance, and organizational structure, consistent with and justified by the aims of the project and the expertise of each of the PDs/PIs?	25
4. The adequacy and suitability of the facilities and research environment	15

2.1.7.5 Variation in the Role of Procurement Between Agencies

While there is some variation in how and what agencies fund, the role of procurement is generally driven by the mission of the particular agency, as mandated by the US Congress. Some of the federal agencies, such as the National Science Foundation, have a greater focus on their mission of promoting basic research. This fundamental mission to promote basic research is reflected in the type of awards and funding for the SBIR. By contrast, other agencies, such as the Department of Defense and NASA, have a greater priority on procurement that is consistent with their missions as mandated by the US Congress and less of a priority on basic research.

Yet, there are several agencies that differ in terms of procurement. The largest funder, the DoD, requires DoD liaisons between the SBIR office and the awardee. The liaisons' explicit role is to introduce the potential technologies into their acquisition program. For example, if an awardee successfully attains a Phase III designation, it is the role of the liaisons to report the potential benefits of the innovation to the DoD acquisitions. Due to the enormous scale of acquisitions conducted by the DoD, the agency desires that these awardees do not get "lost" among the large crowd of acquisition applicants and be therefore flagged as having a Phase III award designation. The DoD, however, is not required to purchase from Phase III awardees.[17]

Another agency, which differs in its procurement methods, is the NIH. Its solicitations are less determined by the procurement needs of the agency and are more consistent with pursuing the quality of the scientific contributions to basic research.

The recipient firm often owns the intellectual property generated from an SBIR award. An example of IP ownership remaining with SBIR awardees is given below:

> "NASA Select SBIR contracts will include FAR 52.227–11 Patent Rights Ownership by the Contractor, which requires the SBIR/STTR contractors to do the following. Contractors must disclose all subject inventions to NASA within 2 months of the inventor's report to the awardees. A subject invention is any invention or discovery, which is or may be patentable, and is conceived or first, actually reduced to practice in the performance of the contract. Once the contractor discloses a subject invention, the contractor has up to 2 years to notify the Government whether it elects to retain title to the subject invention. If the contractor elects to retain title, a patent application covering the subject invention must be filed within 1 year. If the contractor fails to do any of these within time specified periods, the Government has the right to obtain title. To the extent authorized by 35 USC 205, the Government will not make public any information disclosing such inventions, allowing the contractor the permissible time to file a patent."

2.1.7.6 Assessment

With over 90,000 awards given and 20.8 billion dollars distributed, two bothersome questions have been raised about measuring the success of SBIR (Buss 2001; Wallsten 2001). The first involves selection bias: SBIR may award firms that already

[17] Unfortunately, no information could be found on how often DoD purchases products from Phase III funded SBIR awardees.

have the characteristics needed for a higher growth rate and likelihood of survival. The second suggests that SBIR recipients would have engaged in the same innovation projects and R&D investments in the absence of the SBIR funding and was raised in an important study by Wallsten (2000), who finds empirical evidence that being a recipient of an SBIR award does not result in greater R&D spending or innovative activity.

Although enhancing firm growth and survival is an important aspect of SBIR, it does not capture all of the program's benefits. SBIR may benefit the economy by changing the behavior of knowledge workers. For example, Audretsch and Stephan (1996) found that scientists starting biotechnology firms deviated from an academic path or career with a large pharmaceutical corporation. How to induce knowledge workers—particularly scientists and engineers—to change their behavior and take advantage of commercialization opportunities is at the center of the policy debate in European countries such as Germany and France. Although it is important to analyze the impact of a government research and development program such as the SBIR on the ability of firms to survive and grow, such programs may have even more fundamental impact on whether scientists and engineers start the firms in the first place (Audretsch 1995). Empirical evidence suggests that the SBIR has influenced the behavior of knowledge workers in at least two important ways. The first is that it may encourage entrepreneurship for some scientists and engineers who otherwise never would have tried to commercialize their knowledge. The second occurs when successful science-based entrepreneurs, who received SBIR support, influence the behavior of their colleagues by inducing subsequent commercialization. Much literature exists on the importance of learning, but it typically focuses on firms' learning. In contrast, this second aspect focuses on individual knowledge workers learning by observing the choices and outcomes of their colleagues. For example, Audretsch and Stephan (1996) attributed the clustering of scientists working with biotechnology firms in a particular location to the demonstration effect of seeing the success of their entrepreneurial colleagues. Thus, rather than focusing on the diffusion of particular processes, SBIR focuses on the diffusion of behavior (see Fig. 2.6 in Audretsch and Feldman 1996).

SBIR may have another key impact by altering the type of science undertaken. Specifically, Audretsch et al. (2002) have looked at the commercialization impact of SBIR through altering the career trajectories. The authors find that in over half of their case studies (55 % of the survey firms), SBIR induced individuals to start firms who otherwise would not. In one third of the case studies, SBIR induced other colleagues to start science-based firms through the demonstration effect.

In addition, there are indications that the experience of scientists and engineers in commercialization via a small business has an externality by spilling over to influence the career trajectories of colleagues. One quarter of the scientists interviewed in the case studies named specific examples of colleagues who were either starting a new firm or becoming involved in a small firm to commercialize their knowledge. The evidence from the broader survey generally confirms the findings from the case studies.

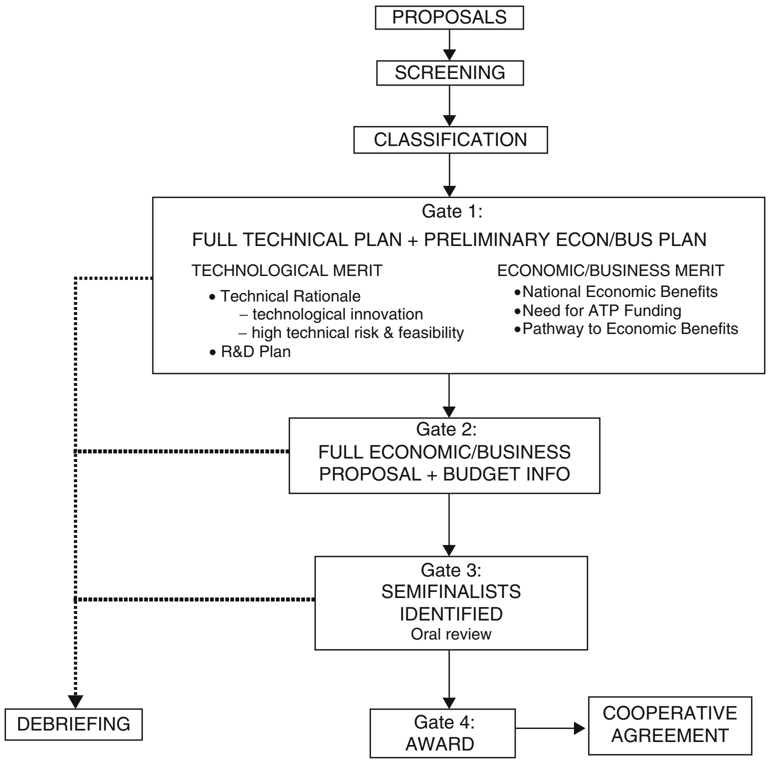

Fig. 2.6 Schematic overview of the ATP selection process. Source: Adapted from Wessner: *The Advanced Technology Program: Assessing Outcomes* (2001) p. 186

Both the policy-makers and scholarship provide the following consistent evidence that:

1. A significant number of the firms would not have been started without SBIR.
2. A significant number of the scientists and engineers would not have become involved in the commercialization process in the absence of SBIR.
3. A significant number of other firms were started because of the demonstration effect by the efforts of scientists to commercialize knowledge.
4. A number of other scientists altered their careers to include commercialization efforts as a result of the demonstration effect by SBIR-funded commercialization.

2.1.7.7 SBIR Cofinancing and Crowding Out

The SBIR program does not require cofinancing from awardees. The primary reason why there is no legal obligation for cofinancing is due to the aforementioned valley of death issue for small innovative firms. The US policy for funding potential innovative products has not addressed the issue of crowding out of potential private venture capitalists. To date, no scholarly research has addressed, in a systematic fashion, to what degree, if any, crowding out has occurred. Yet, at least on a theoretical level, one can assume that the SBIR program is simply a policy instrument designed to help potential entrepreneurs bridge the valley of death when they are unable to attract or find appropriate private venture capital. Due to the higher transaction costs of dealing with government and the lack of Phase III funding, one can assume there would be a clear preference for potential innovators to select private investment rather than public investment, which implies that the risk of crowding-out funding from private sources is likely to be small.

2.1.7.8 The Role of Phase III

Most of the agencies do not offer funding for Phase III awards. NASA and the Department of Defense may selectively offer small funding for Phase III awards, but the primary purpose of the award is simply to serve as a signal that the SBIR awardee has successfully completed Phase I and II and is therefore at the potential stage of production. This signal can play an important role in that the awardee works almost exclusively with one agency, such as NASA, and therefore has an understanding of the agency's operating procedure and the institutional norms necessary to successfully complete a potential project.

In fact, there are also institutional problems in federal procurement of Phase III products. Federal procurement rules are generally very rigid and cost intensive for selling products. Procurement regulations require many new firms to have higher compliance and overhead, which therefore give incumbent firms a competitive cost advantage when acquiring federal contracts. Indeed, the 11 agencies that are authorized to acquire products may also have a bias against SBIR firms due to the aforementioned mandated 2.5 % R&D budget allocation going to SBIR firms.[18]

Many of the Phase II awardees have asked the question, what is Phase III good for? (Wessner 2006). Yet, many feel that the recognition of being a Phase III awardee, having been independently selected by an agency, adds a degree of legitimacy to any potential procurement bid they elect to submit. However, most of the Phase III awardees believe that there is a missing element of large-scale finance which they require in order to become profitable.

2.1.8 The Advanced Technology Program (ATP)

During the late 1980s, the United States faced increasing competition from highly innovative Japanese firms. Policy-makers concluded that some sort of policy instrument was needed in response to the advancing Japanese technologies, such as the electronic or automotive industry, which were outcompeting the United States. In response to this innovation gap between the United States and Japan and also to the

[18] Procurement officers may view this mandate as a loss of resources on the particular agency and therefore would be less willing to buy the final product that their agency has been mandated to fund.

recession in 1990, policy-makers and the congress decided to enact legislation which would enable private firms to acquire funding to help them commercialize ideas with market potential.

In 1991, special legislation created the Advanced Technology Program (ATP), which was designed to help industry develop ideas into innovations and serve as a governmental conduit between the research laboratory and the commercial market. ATP's express mission is to help manifest ideas into commercially applicable innovations. The National Institute of Standards and Technology (NIST), US Department of Commerce, ran ATP. As shown in Table 2.6, ATP supported 1581 different participants with over $4,614,000,000 of funding. ATP belonged to the National Institute of Standards and Technology, a subsection of the Department of Commerce, during its program life from 1991 to 2007. Due to its $136 million budget in 2006, the George W. Bush administration terminated the program in 2007. A new Technology Innovation Program (TIP) established by the 2007 America COMPETES Act (Public Law 110–69) succeeded the ATP program.

Table 2.6 Advanced Technology Program projects, number of participants, and funding: FY 1990–2007

Project funding (current $millions)						ATP			Industry		
Fiscal year	Projects	SA	JV	Participants	Total	All	To JV	To SA	All	From JV	From SA
1990	11	6	5	35	98	46	38	8	52	45	7
1991	28	18	10	83	202	93	65	28	109	83	26
1992	21	18	3	32	97	48	19	29	49	19	30
1993	29	24	5	50	118	60	19	41	58	20	38
1994	88	50	38	211	640	309	216	93	331	233	98
1995	103	62	41	318	827	414	304	110	413	340	73
1996	8	6	2	12	37	19	9	10	18	10	8
1997	64	49	15	101	304	162	75	87	142	81	61
1998	79	52	27	168	460	235	143	92	225	157	68
1999	37	26	11	57	212	110	61	49	102	64	38
2000	54	39	15	95	274	144	70	74	130	74	56
2001	59	46	13	88	286	164	79	85	122	81	41
2002	61	51	10	79	289	156	59	97	133	61	72
2003	67	55	12	104	257	154	49	105	103	51	52
2004	59	48	11	78	270	155	62	93	115	66	49
2005	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0
2007	56	47	9	70	243	139	47	92	104	50	54

Notes: For multiyear projects, total funding was attributed to the year award was made. Participants include SAs, JV leaders, and JV members and exclude subcontractors and informal collaborators. Beginning in 2000, funding and number of awards were based on the year recipient received funding, not on competition year

ATP Advanced Technology Program, *JV* joint ventures, *SA* single applicants

Source: Adapted from National Science Board, *Science and Engineering Indicators 2010*

During its 17-year life, the program's uniqueness attracted considerable attention from both policy-makers and scholars. It was seen as one of the first attempts by policy-makers to deliver a governmental organization which could help firms in a knowledge economy context, after an industrial era, the latest from World War II to the fall of the Berlin Wall in 1989.

From a policy prospective, the ATP not only served as a bridge but also tried to identify the positive externalities of innovation. For example, a US-based firm may be unwilling to invest its resources in a potential *idea* due to its perceived lack of return, but the potential *innovation* would have positive benefits to the economy as a whole if commercialized. While this innovation may have produced highly positive benefits to the economy as a whole, its benefit to the particular firm would be unrealized and therefore remain dormant. ATP's mission therefore was to view R&D projects from a macro- rather than a microperspective, i.e., can this idea benefit the nation, not just the company? ATP's design was to share relatively high risks of developing technologies, which potentially had a broad range of new commercial opportunities. The ATP mission differed from other government R&D programs in that:

- "ATP projects focused on the technology needs of American industry, not those of government. Research priorities for the ATP are set by industry, based on their understanding of the marketplace and research opportunities. For-profit companies conceive, propose, co-fund, and execute ATP projects and programs in partnerships with academia, independent research organizations and federal labs.
- The ATP had strict cost-sharing rules. Joint ventures (two or more companies working together) had to pay at least half of the project costs. Large, *Fortune 500* companies participating as a single firm had to pay at least 60 % of total project costs. Small- and medium-sized companies working on single-firm ATP projects had to pay a minimum of all indirect costs associated with the project.
- The ATP did not fund product development. Private industry bears the costs of product development, production, marketing, sales, and distribution.
- The ATP awards were made strictly on the basis of rigorous peer-reviewed competitions. Selection was based on the innovation, the technical risk, potential economic benefits to the nation, and the strength of the commercialization plan of the project.
- The ATP's support did not become a perpetual subsidy or entitlement—each project had goals, specific funding allocations, and completion dates established at the outset. Projects were monitored and could be terminated for cause before completion."[19]

2.1.8.1 ATP Design

The ATP partnered with companies of all sizes, universities, and nonprofits, encouraging them to take on greater technical challenges with potentially large benefits that extended well beyond the innovators—challenges they could not or would not

[19] Adapted from: http://www.atp.nist.gov/atp/overview.htm

face alone. For smaller, start-up firms, early support from the ATP could spell the difference between success and failure. More than half of the ATP awards went to individual small businesses or to joint ventures led by a small business. Large firms worked with the ATP, especially in joint ventures, to develop critical, high-risk technologies that would have been difficult for any one company to justify because, for example, the benefits were spread across the industry as a whole.

Universities and nonprofit independent research organizations played a significant role as participants in ATP projects. Out of 768 projects selected by the ATP from its inception, well over half of the projects included one or more universities as either subcontractors or joint-venture members. All told, more than 170 individual universities and over 30 national laboratories participated in ATP projects.

ATP awards were selected through open, peer-reviewed competitions. All industries and all fields of science and technology were eligible. Proposals were evaluated by one of several technology-specific boards that were staffed with experts in fields such as biotechnology, photonics, chemistry, manufacturing, information technology, or materials. All proposals could be sure of an appropriate, technically competent review even if they involved a broad, multidisciplinary mix of technologies. As shown in Fig. 2.6, the schematic overview of the ATP selection process clearly illustrates the degree to which proposals were properly screened and identified for potential positive externalities to the economy.

2.1.8.2 Assessment of ATP

A rich and compelling literature has been generated which identifies and analyzes the impact of specific public policy programs and instruments, such as ATP, on the economic and technological performance and strategies of firms. Branscomb and Auerswald (2002), for example, found that ATP awards help bridge a funding gap left by venture capitalists, what the authors refer to as *the valley of death*. Feldman and Kelley (2002) find that ATP fosters knowledge spillovers leading ATP-funded projects to produce not only firm-specific benefits but broad national economic benefits as well. The same study shows that, in the absence of ATP awards, firms are not likely to proceed with any aspect of their proposed project on their own. Studies evaluating the impact of ATP have also shown that an ATP award creates a halo effect, also known as reputation effect, for participating firms, increasing their chances of attracting additional funding from other sources (Feldman and Kelley 2000, 2001; Powell and Lellock 1997). Other studies have assessed the impact of federal programs like ATP, DARPA, and SBIR in terms of their effect on firm growth and productivity, employment size, number of patents secured, R&D cycle time, and other related metrics (Advanced Technology Program Economic Assessment Office 2004; Silber and Associates 1996).

This literature has been guided by the most prevalent theory of firm innovation in economics—the model of the knowledge production function. This was formally introduced by Griliches (1979) and links innovative outputs to knowledge inputs. Just as this theory takes the firms as given, or exogenous, and then analyzes their innovative and economic performance as a result of purposeful and targeted investments to create and commercialize new knowledge, the impact of public policy has generally been analyzed by examining the performance of existing firms. While the exact nature and magnitude of public policy on firm performance varies somewhat depending upon the particular type of policy and study, the focus and therefore the return accruing from public policies such as ATP and SBIR have been largely restricted to improvement in the economic and technological performance of recipient firms.

2.1.9 The DARPA Program

The Defense Advanced Research Projects Agency (DARPA) is an agency with a long history of advanced technology development for the US Department of Defense. With the increasing threat of Soviet Union military hegemony in the late 1950s, the US Congress and military created a program to prevent technological surprises, like Sputnik, and to induce technological advancement in the Space Race in the 1960s. While its original mission was meant to develop space age technologies, DARPA increased the scope and scale of its mission from the 1960s to the 2000s. Today, DARPA employs over 300 people and has an annual operating budget of $3.2 billion. Over the course of the past 50 years, the agency is widely regarded as having developed computer networking, hypertext, graphical user interface, stealth technology, and drone networking.

The agency's current budget for 2015 is 2.92 billion dollars. Around 140 technical scientists work for the agency, which is headquartered in Arlington, Virginia. The agency is explicitly mandated to advance the US military technology and works closely with all areas of the US military service to coordinate and develop existing technological needs. DARPA is widely considered to have the highest R&D investment per scientist in the world.

Today, the agency is considered to be one of the most advanced and secretive institutions in the US government. Indeed, this agency is often cited as similar to something from the Men in Black movie series, where a select few people develop future technologies unknown to the public or private market. For example, some of the projects selected, which are currently or were funded, include the "Transformer" where the goal is to create a flying armored car, "Human Universal Load Carrier" where the goal is to create a battery-powered human exoskeleton, or "EATR" where the goal is to create a robotic soldier.

The structure of DARPA is best described as a group of small organized teams with short-term goals. Given the enormous budget, one would expect some degree of hierarchy; yet, there is little. The self-described motto of DARPA is "100 geniuses connected by a travel agent." Their technological goals are set within a 2–4-year time frame, and they are given almost complete autonomy to complete their projects as they see fit. The primary measure of success for these small groups is whether they have created radical technological innovations during their tenure, during which they had an almost unlimited budget.

DARPA maintains six different program offices, which are dedicated to choosing the best and brightest scientists and project bids every 4–6 years and overseeing and coordinating 140 scientists in their respective fields. The DARPA director is routinely changed to ensure fresh and new ideas are introduced into the agency paradigm.

While DARPA has advanced a plethora of US military technologies, it remains to be seen to what degree these advancements have crossed the knowledge filter barrier and have actually entered the commercial market. Due to the top-secret nature of these advancements, patents are not for public use, nor for competing countries, and the private market has no knowledge of how to endogenize these radical innovations.

DARPA is designed to remain independent from the military's more traditional R&D programs. The distinguishing factor between these two types of military program is that DARPA's explicit mission is to fund and deliver radical innovations for the US military. There are, however, several problems in evaluating DARPA's contribution to the US innovation. Due to the secrecy surrounding military inventions, the returns on this significant investment remain relatively enigmatic. One should note the strong relationships to universities committed to basic research. The MIT, University of Alabama, Carnegie Mellon University, Harvard University, and University of California system receive substantial funding for military research.

Another interesting aspect of DARPA is that during the budget cuts in the mid-1970s, DARPA made significant cuts to its computer networking program. These cuts resulted in several key scientists to start up computer network companies and create private research labs such as the Xerox Palo Alto Research Center, Incorporated. Unlike SBIR and ATP, DARPA's structural design is much more like a lab of creativity and innovation and less like a typical bureaucratic organization. DARPA assigns funding to 2–4-year projects where there is a high degree of potential radical innovations. These projects are overseen by highly educated DARPA staffs who, in conjunction with university scientists and industry research labs, attempt to create advanced military applications.

2.1.10 The Role of Other US Agencies in Innovation

2.1.10.1 Technology Innovation Program (TIP)

The Technology Innovation Program (TIP) was established by the 2007 America COMPETES Act, at the National Institute of Standards and Technology (NIST), US Department of Commerce. Its mission is to assist US businesses and universities to support, promote, and accelerate innovation in the United States through high-risk, high-reward research Technology Innovation Program (2011). Its stated mission is to promote projects which:

- **Have a novel purpose**: addressing societal challenges not being addressed in areas of critical national need with benefits that extend significantly beyond proposers
- **Offer solutions to societal challenges**: concentrating on those challenges that justify government attention

- **Have scientific and technical merit**: supporting innovative high-risk, high-reward research
- **Promise transformational results**: focusing on ideas with a strong potential to advance state-of-the-art and contribute to the US science and technology base
- **Involve rich teaming**: funding small- and medium-sized businesses, academia, national labs, nonprofit research institutions, and other organizations
- **Fulfill a clear government need**: addressing problems that require government attention because the magnitude of the problem is large and no other sources of funding are reasonably available
- **Provide funding**: single company projects up to $3 M over a maximum of 3 years, joint venture projects up to $9 M over a maximum of 5 years
- **Share costs**: requiring proposers to cover at least 50 % of the costs[20]

2.1.10.2 Small Business Technology Transfer Program (STTR)

The Small Business Technology Transfer (STTR) program is in many ways identical to the SBIR program. However, its core mission is to fund small companies, which work in collaboration with universities. Another difference is that instead of the 2.5 % reserved for SBIR funding by the 11 different agencies, STTR requires that five agencies[21] reserve 0.3 % of their budget for STTR funding. A total of $1.3 billion was awarded to over 6000 projects from 1994 to 2006. Each awarded project required a university partner and was awarded Phase I and Phase II awards, according to the SBIR scheme.

2.1.10.3 Hollings Manufacturing Extension Partnership (MEP)

The Hollings Manufacturing Extension Partnership (MEP) is a national network of 60 centers across the United States. This agency, unlike other federal agencies, is run at state level. The purpose of these centers in all 50 states is to focus R&D efforts on technology acceleration, supplier development, sustainability, and workforce improvement. Its explicit purpose is to help manufacturers develop and create new markets and products, thus giving a competitive advantage to US firms.

2.1.11 Lessons that Can Be Learned from These Programs

The previous sections of this report have established that there is empirical evidence that the main innovation programs in the United States—the SBIR, ATP, and DARPA—have generally exerted a positive influence on innovative activity. While

[20] See: http://www.nist.gov/tip/factsheets/upload/tip_at_a_glance_2011.pdf

[21] The Department of Defense, the National Science Foundation, The Department of Energy, NASA, and Health and Human Services

there is no reason to conclude that these programs in any way constitute an optimal policy to promote innovative activity, competitiveness, and ultimately economic growth, the empirical evidence does suggest they have had a positive impact on the innovative performance of the United States.

This section considers the adaptability of these programs to other countries from two perspectives. The first is whether the actual delivery and administration of the programs can be replicated. The second is whether others can achieve similar capabilities and outcomes from the programs.

From the first perspective, the authors of this chapter believe that the answer to whether US innovation programs can be applied to other countries (i.e., duplicating the exact programs and administration) is improbable. This is because of the central role played by US federal institutions in the design and administration of the US innovation programs. The SBIR, in particular, depends on the main federal agencies allocating a share of their research budgets to small innovative firms. Administered by federal agencies such as the US Department of Defense, the SBIR enjoys support from a mission-oriented approach to innovation.

Other countries have no agencies that are equivalent to, say, the US Department of Defense, either in terms of size or scope. Taken from the first perspective, this would seemingly preclude the applicability of the US innovation policy approach to other countries.

However, it should be emphasized that the policy approach to the US innovation programs is a second-best approach. The SBIR, ATP, and DARPA programs promote and facilitate entrepreneurial innovation indirectly in that the administering agencies do not have commercialization and innovation as their primary and explicit mandates. This approach was not adopted in the United States because it was considered to be the most effective way to promote innovation, competitiveness, and growth but rather as a second-best option. It was not considered politically feasible to create new agencies and programs that directly promote innovation. Thus, the current approach in the United States was adopted because it was considered to be politically feasible and not because it was considered to be the best way to foster innovative activity.

Thus, it may be the second perspective that is the most relevant and important in considering the applicability of the US programs to other contexts. Here, the focus is not on exactly duplicating the exact programs and administration but rather on achieving similar capabilities and outcomes. The capabilities would be in terms of innovative capabilities of the local firms and the outcomes would be in terms of the innovative performance of the local firms.

Rather than administer such innovation programs indirectly through existing ministries and agencies already mandated with a different mission, as is the case in the United States, other countries have the potential to establish agencies and ministries with a main mandate to promote innovation. Such an approach would consist of three phases—feasibility, research, and commercialization. Applicant firms and nascent entrepreneurs would make an application based on these three phases. The applications would be subjected to a competitive assessment.

The first phase would focus on the feasibility of the idea. The second phase would include those ideas developed in the first phase that are the most innovative and embody the greatest potential commercial impact. The funding in the second phase would be to develop the idea into a workable prototype. The third phase would involve actual commercialization. In this third phase, the firm would actually introduce the innovative product, conceptualized during the first phase and developed into a prototype in the second phase, onto the market.

During the first two phases, the innovative activity would be funded entirely by the relevant innovation-funding agency. However, the resulting intellectual property would remain with the company undertaking the innovative activity. This is a form of pre-commercial procurement that policy can deploy for innovative activity in priority areas. For example, specific social issues could be assigned a high priority by the relevant agency. In the third phase, both the firm and the funding agency could share funding. This approach to innovative programs could fit the institutional context of other countries that do not have the equivalent of large US mission-oriented agencies.

2.2 The Role of Local Institutions (Universities and Regions/States)

This section illustrates the importance of local institutions in R&D and innovation. Given that over one third of *total* R&D is allocated to universities, it is imperative to understand what institutions are likely to facilitate growth. Moreover, are certain individuals more likely to be inclined to transform ideas into innovations for the local region? If so, how can local institutions, laws, and incentives create more innovation in the knowledge economy context?

2.2.1 The Relevance of Universities and Regions/States in Fostering the Knowledge Economy

Why will scientists choose to combine their scientific creativity with entrepreneurial creativity? There are a number of theories and hypotheses as to why some scientists choose to commercialize research while others do not, and some compelling insights have been garnered through previous empirical studies. These include the scientist life cycle which highlights the role of reputation, the knowledge production function which highlights the role of scientific human capital and resources, and the regional and university contexts which highlight the role of geographically bounded spillovers and institutional incentives.

A large body of literature has emerged focusing on what has become known as the appropriability problem. The underlying issue revolves around how firms, which invest in the creation of new knowledge, can best appropriate the economic returns from that knowledge (Arrow 1962). Audretsch (1995) proposed shifting the unit of observation away from exogenously assumed firms to individuals—agents with endowments of new economic knowledge. When the focus is shifted away from the firm to the individual as the relevant unit of analysis, the appropriability issue remains, but the question becomes, “How can scientists with a given endowment of new knowledge best appropriate the returns from that knowledge?” Levin and Stephan (1991) suggest that the answer is “It depends—it depends on both the career trajectory as well as the stage of the life-cycle of the scientist.”

The university or academic career trajectory encourages and rewards the production of new scientific knowledge. Thus, the goal of the scientist in the university context is to establish *priority*. This is done most efficiently through publication in scientific journals (Stephan and Audretsch 2000). By contrast, with a career trajectory in the private sector, scientists are rewarded for the production of new economic knowledge, or knowledge, which has been commercialized in the market but not necessarily new scientific knowledge per se. In fact, scientists working in industry are often discouraged from sharing knowledge externally with the scientific community through publication. As a result of these different incentive structures, industrial and academic scientists develop distinct career trajectories.

The appropriability question confronting academic scientists can be considered in the context of the model of scientist human capital over the life cycle. Scientist life-cycle models suggest that early in their careers, scientists invest heavily in human capital in order to build a scientific reputation (Levin and Stephan 1991) that signals the value of their knowledge to the scientific community.

With maturity, scientists seek ways to appropriate the economic value of the new knowledge. Thus, academic scientists may seek to commercialize their scientific research within a life-cycle context. The life-cycle model of the scientist implies that, *ceteris paribus*, scientist reputation should play a role in the decision to commercialize.

An implication of the knowledge production function formalized by Griliches (1979) is that those scientists with greater research and scientific prowess have the capacity to generate greater scientific output. But how does scientific capability translate into observable characteristics that can promote or impede commercialization efforts? Because the commercialization of scientific research is particularly risky and uncertain (Stephan and Audretsch 2000), a strong scientific reputation, as evidenced through vigorous publication and formidable citations, provides a greatly valued signal of scientific credibility and capability to any anticipated commercialized venture or project. This suggests a hypothesis which links measures of the quality of the scientist, or his/her scientific reputation as measured by citations and publications, to commercialization.

Scientist location can influence the decision to commercialize for two reasons. First, as Jaffe (1989), Audretsch and Feldman (1996), Jaffe et al. (1993), and Glaeser et al. (1992) show, knowledge tends to spill over within geographically bounded regions or clusters. This implies that scientists working in regions with a high level of investments in new knowledge can more easily access and generate new scientific ideas. This suggests that scientists working in knowledge clusters tend to be more productive than their counterparts who are geographically isolated from other sources of knowledge.

A second component of externalities involves not the technological knowledge but rather behavioral knowledge. As Bercovitz and Feldman (2003) show in a study based on the scientists' commercialization activities at Johns Hopkins and Duke University, the likelihood of a scientist engaging in commercialization activity, which is measured as disclosing an invention, is influenced by the commercialization behavior of the doctoral supervisor in the institution where the scientist was trained. The commercialization behavior and attitudes exhibited by the chair and peers at the relevant department also have an effect.

Thus, the locational and institutional contexts can influence the propensity of scientists to engage in commercialization activities by providing access to spatially bounded knowledge spillovers and by shaping the institutional setting and behavioral norms and attitudes toward commercialization.

Globalization has triggered a shift in the comparative advantage of leading developed countries away from the factor of capital and toward knowledge. For the factor of knowledge to be effective in generating employment, economic growth, and international competitiveness, it must spill over to become commercialized (Acs and Audretsch 2003; Siegel et al. 2003b). As Acs et al. (2005) and Audretsch et al. (2006a, b) emphasize, such knowledge spillovers are not automatic and cannot be assumed to exist. Thus, in terms of Richard Florida's insights about creativity, investments in scientific creativity need to be combined with commercial creativity to facilitate knowledge spillovers that can ultimately contribute to economic growth Florida (1999). Scientists who choose to commercialize their research can combine such scientific creativity with commercial creativity.

This report has identified why some scientists choose to combine scientific and commercial creativity while others do not. In particular, the human capital and reputation of the scientist play an important part, as does the context, in terms of location and particular type of institution where the scientist is employed. The evidence suggests that scientists with the most knowledge have a higher propensity to commercialize their research. However, the type of university and the region habituates scientist commercialization.

2.2.2 Complementarities between Centrally vs. Locally Based Policies

2.2.2.1 The Role of Universities and the Bayh-Dole Act in Economic Growth and Innovation

When the Bayh-Dole Act was passed in 1980, it was a direct response to the US international competitiveness crisis of the 1970s. The Bayh-Dole Act shifted intellectual property rights created through federally funded research from the government to the university. As Senator Birch Bayh pointed out, "A wealth of scientific talent at American colleges and universities—talent responsible for the development of numerous innovative scientific breakthroughs each year—is going to waste as a result of bureaucratic red tape and illogical government regulations… What sense does it make to spend billions of dollars each year on government-supported research and then prevent new development from benefiting the American people because of dumb bureaucratic red tape?"[22]

One important aspect of such technology infrastructure in the United States involves both the passage of the Bayh-Dole Act and its application. The Bayh-Dole Act has not only provided the requisite infrastructure to enable entrepreneurial activity to emerge out of universities, but it has also enabled "other actors," and in particular university scientists, to participate in the innovation process, when previously they might have been excluded.

The Bayh-Dole Act paved the way for the widespread diffusion of the university technology transfer office (TTO), which has served as a mechanism, or instrument, to facilitate the commercialization of university scientific research and to harness the ensuing revenue streams for the university. In fact, examples of technology transfer offices existed prior to 1980, but some three decades subsequent to the act's passage, virtually every major US university now has a TTO. The main mission of the TTO is to collect the intellectual property disclosed by scientists to the university and to encourage commercialization where deemed feasible and appropriate Siegel and Phan (2005).

The Association of University Technology Managers (AUTM) collects and reports a number of measures reflecting the intellectual property and commercialization by its member universities. A voluminous and growing body of research has emerged which documents the impact of TTOs on the commercialization of university research. Most of these studies focus on various measures of output associated with university TTOs (see Chap. 5, Richardson, Audretsch, Aldridge, and Nadella.) By most accounts, the impact of the TTO on facilitating the commercialization of university science research was so impressive that by the turn of the century, the Bayh-Dole Act was being celebrated as an unequivocal success: "Possibly the most inspired piece of legislation to be enacted in America over the past half-century was the Bayh-Dole Act of 1980."[23] With amendments in 1984 and augmentation in 1986, this act unlocked all the inventions and discoveries that had been made in laboratories throughout the United States with the help of taxpayers' money. More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance. "Before Bayh-Dole, the fruits of research supported by government agencies had gone strictly to the federal government. Nobody could exploit this research without tedious negotiations with the federal agency concerned. Worse, companies found it nearly impossible to acquire exclusive rights to a government-owned patent. And without that, few firms were willing to invest millions more of their own money to turn a basic research idea into a marketable product."[24]

In an even more enthusiastic assessment of the Bayh-Dole Act, *The Economist* (2002) gushed, "The Bayh-Dole Act turned out to be the Viagra for campus innovation.

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[22] Statement by Birch Bayh, April 13, 1980, on the approval of S. 414 (Bayh-Dole) by the US Senate on a 91-4 vote, cited from AUTM (2004, p. 16), and introductory statement of Birch Bayh, September 13, 1978, cited from the Association of University Technology Managers Report (AUTM) (2004, p. 5)

[23] "Innovation's Golden Goose," *The Economist*, 12 December 2002.

[24] "Innovation's Golden Goose," *The Economist*, 12 December 2002.

Universities that would previously have let their intellectual property lie fallow began filing for—and getting—patents at unprecedented rates. Coupled with other legal, economic and political developments that also spurred patenting and licensing, the results seems nothing less than a major boost to national economic growth."[25]

Despite the generally giddy assessments of Bayh-Dole, Mowery (2005, pp. 40–41) has argued for a more cautious and balanced perspective: "Although it seems clear that the criticism of high-technology start-ups that was widespread during the period of pessimism over US competitiveness was overstated, the recent focus on patenting and licensing as the essential ingredient in university–industry collaboration and knowledge transfer may be no less exaggerated. The emphasis on the Bayh-Dole Act as a catalyst to these interactions also seems somewhat misplaced."

However, there are compelling reasons to suspect that not all of the intellectual property created through the university is commercialized through the TTO (Thursby and Thursby 2005). In particular, a university's TTO may be overwhelmed with intellectual property disclosures, forcing it to select and focus on only a subset of the most promising projects. Shane (2004, p. 4) suggests that by resorting to what he refers to as the backdoor, scientist commercialization does not always proceed through the implicit front door of the technology transfer, Shane (2004, p. 4) finds that, "Sometimes patents, copyrights and other legal mechanisms are used to protect the intellectual property that leads to spin-offs, while at other times the intellectual property that leads to a spin-off company formation takes the form of know how or trade secrets. Moreover, sometimes entrepreneurs create university spin-offs by licensing university inventions, while at other times the spin-offs are created without the intellectual property being formally licensed from the institution in which it was created. These distinctions are important for two reasons. First it is harder for researchers to measure the formation of spin-off companies created to exploit intellectual property that is not protected by legal mechanisms or that has not been disclosed by inventors to university administrators. As a result, this book probably underestimates the spin-off activity generated when exploiting inventions that are neither patented nor protected by copyrights. This finding also underestimates the spin-off activity that occurs 'through the back door': that is, companies founded to exploit technologies that investors fail to disclose to university administrators."

There is little empirical evidence to support Shane's admonition that relying upon the data collected by the TTOs and aggregated by AUTM will obscure the extent to which scientists resort to backdoor commercialization. Field studies (Siegel et al. 2003a and Link et al. 2007) and research from a survey (Thursby and Thursby 2002), along with two university case studies (Bercovitz and Feldman 2006), clearly highlight the vigorous propensity of some scientists to resort to informal and backdoor activities rather than front door activities through the TTO for commercializing their research. As shown in Fig. 2.7, the American University

[25] Cited in Mowery 2005 D. Mowery, The Bayh-Dole Act and High-technology Entrepreneurship in US Universities: Chicken, Egg, or Something Else? Colloquium on Entrepreneurship Education and Technology Transfer, University of Arizona (2005) (21–22 January). Mowery (2005, p. 64).

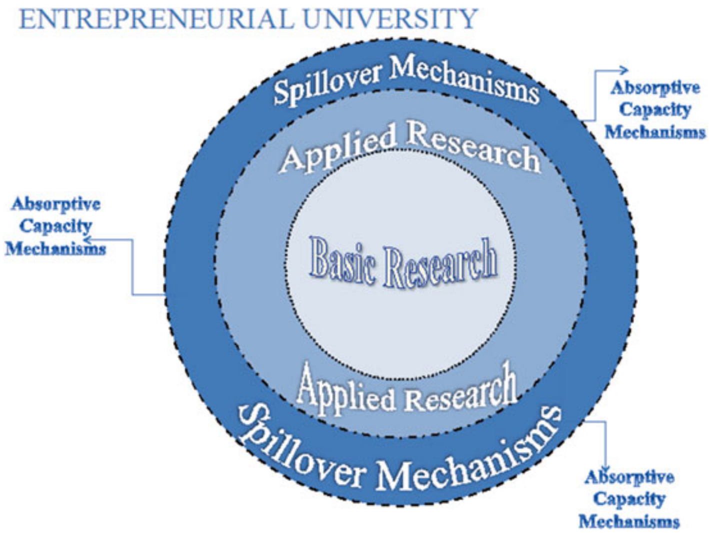

Fig. 2.7 The entrepreneurial university

innovation ecosystem has developed significantly over the past 30 years as to where part of a universities primary mission is knowledge diffusion and profit maximization of its intellectual property.

One empirical analysis of the implemented of the Bayh-Dole Act in Europe and other countries describes the abolishment of the "professor privilege" conducted by Czarnitzki et al. (2011). The paper finds that the abolishment of the "professor privilege" led to an acceleration of the decline in patent forward citations. Due to the structural change in Germany, professors no longer had to bear the cost of funding patent applications, and the cost was borne by the professor's institution. The authors find that the overall quality of forward citations declined after the introduction of the German Bayh-Dole Act. To a large degree these findings are rather unsurprising for several reasons. For example, prior to the "professor privilege," one would expect only the most certain and potentially successful patents to be registered by the professor, since he/she would have to bear not only the cost of the patent application, but also be responsible for commercializing the potential innovation, i.e., only the most certain patents with a very high general quality would be issued. After the abolition of the "professor privilege," the cost of a patent application was less for a university scientist, thereby increasing the number of patents filed. This therefore lowered the average general quality of total patents issued by university professors.

It is important to understand, when dealing with the entrepreneurial university, that whatever a patent has created, there must be proper institutional mechanisms for it to become an active innovation. As Aldridge and Audretsch (2010, 2011) demonstrate, US professors are starting companies in far greater numbers than previously recorded, and they also tend to not register their "best" quality patents with their respective universities.

2.2.2.2 Role of Regions/States in Fostering the Knowledge Economy and Growth

Recognition of the role that firm-specific knowledge investments could play in accessing and absorbing external knowledge, and therefore enhancing the innovative output of the firm, triggered an explosion of studies focusing on potential sources of knowledge that are external to the firm. Some studies examined the role of licensing, cooperative agreements, and strategic partnerships, all of which involve a formal agreement and a market transaction for the sale of knowledge. Thus, these all represent mechanisms by which a firm can access knowledge produced by another firm (but this might require previous internal investments in knowledge that are a prerequisite for absorbing such external knowledge, see Cohen and Levinthal 1989).

Compelling and consistent evidence provided first by Jaffe (1989), but later confirmed by Acs et al. (1992, 1994), Feldman (1994a, b), Jaffe et al. (1993), and Audretsch and Feldman (1996), suggested that, in fact, the presence of external knowledge sources in geographically bounded regions increased the innovative output of firms located in those regions. Thus, there was clear and compelling econometric evidence suggesting that external investments in clustered regions would yield an increased level of innovative output by the firms located in that region as a result of knowledge spillovers.

The new findings from the studies on spatially bounded knowledge spillovers supported the knowledge production model of firm innovation in two main ways. First, the firms were still assumed to be exogenous, and second, knowledge inputs were still found to be important determinants of innovative output. The main distinction lies in the unit of analysis. Because of knowledge spillovers, the link between knowledge inputs and firm innovative output was found to be more important for spatial units of observation than at the level of the firm.

The geography of firms has important implications on the spatial distribution of the impact of public policies directed at stimulating innovative behavior. It is already well documented that not only university research, venture capital, scientists and engineers, high-technology firms, and start-ups tend to cluster in spatial agglomerations (Saxenian 1994), but federal support of innovation, such as the ATP and SBIR (Fig. 2.8), also tends to be spatially concentrated in exactly these areas (Audretsch et al. 2002).

The spatial correlation of knowledge assets, high-technology programs, and federal programs such as ATP and SBIR suggests that a "winner takes all" policy may be emerging across regions. Those regions that have already established a successful high-technology cluster are able to generate knowledge spillovers, attract firms, scientists, and engineers, as well as draw a high share of federal support for innovation to their regions. By contrast, regions that have been technologically disadvantaged or have not yet developed knowledge-based clusters tend to experience difficulties in procuring a high share of federal support for innovation (see Fig. 2.8

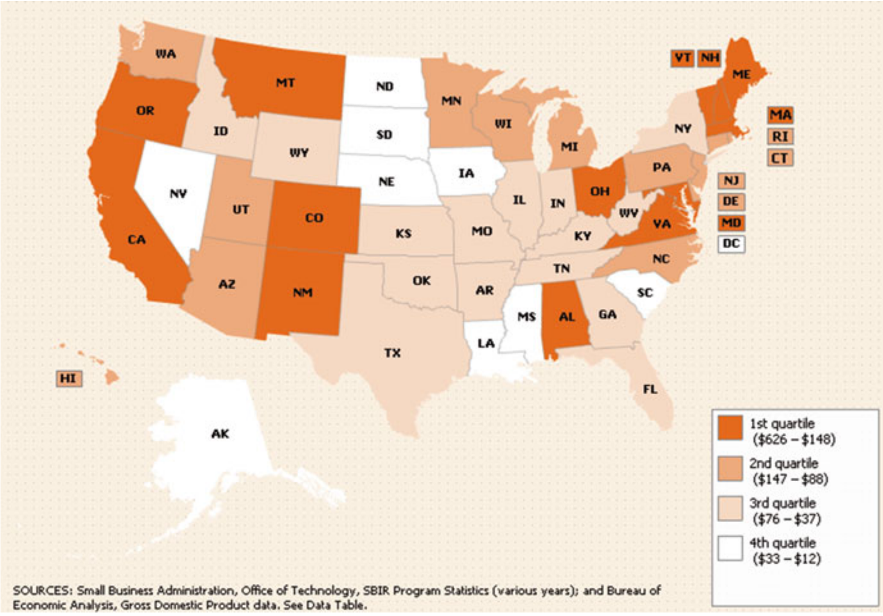

Fig. 2.8 Average annual federal SBIR funding per $1 million of gross domestic product: 2006–2008

and Table 2.7). This raises the question about the relative contribution made by public policies at the federal level that have a local impact: *Is there greater impact in existing successful high-technology agglomerations, where the technology firms are already established and knowledge spills over without being impeded by a filter, or would public policy at the federal level have a greater, or at least different, impact in regions that have not yet established viable high-technology agglomerations?*

2.3 Lessons from the US Programs

This section offers several key policy implications, which can be drawn from the US programs to fit the context of other countries. The primary problems of replicating a SBIR-type institution are identified and addressed.

There is little doubt that the US public innovation system has provided robust and significant contributions to the economic growth of small- and medium-sized enterprises (Wessner 2011). To what degree can this contribution be replicated in other countries' institutional mechanisms remains an open question, given that the US system is predicated on several consistent and important features.

Table 2.7 Advanced Technology Program, ongoing/completed projects, project-level award amounts ($M), summed by the state

State	Number of projects	ATP awards ($M)	Industry share ($M)	Total ($M)
Alabama	1	$3.3	$3.5	$6.8
Arizona	5	$16.6	$14	$30.6
California	120	$360.7	$353.6	$714.3
Colorado	8	$15	$8.5	$23.5
Connecticut	19	$55.3	$55.5	$110.8
Delaware	5	$9.4	$7.6	$17
Florida	7	$28.7	$29.8	$58.5
Georgia	6	$12.3	$7.2	$19.5
Illinois	21	$71.3	$75.7	$147
Indiana	2	$3.6	$3.2	$6.8
Iowa	2	$2.6	$1.4	$4
Louisiana	2	$3.8	$3.1	$6.9
Maryland	16	$50	$45	$95
Massachusetts	48	$96.2	$78.1	$174.3
Michigan	41	$182.4	$192.2	$374.6
Minnesota	17	$60.9	$70.3	$131.2
Missouri	1	$2	$1.4	$3.4
Nebraska	1	$2	$0.9	$2.9
New	2	$4	$1	$5
New Jersey	26	$88.1	$95.5	$183.6
New Mexico	1	$2	$1.8	$3.8
New York	29	$72.1	$73.7	$145.8
North Carolina	7	$34.4	$33.1	$67.5
Ohio	17	$70.6	$71.6	$142.2
Oklahoma	2	$3.5	$3	$6.5
Oregon	8	$18.9	$17.7	$36.6
Pennsylvania	18	$57.1	$61.8	$118.9
Rhode Island	3	$4.4	$2.6	$7
South Carolina	3	$41.4	$48	$89.4
Texas	18	$59.7	$53.1	$112.8
Utah	8	$15.2	$12.9	$28.1
Virginia	10	$31.1	$23.3	$54.4
Washington	2	$3.9	$1.4	$5.3
Wisconsin	5	$9	$6.1	$15.1
State count	Project count	Total ATP ($M)	Total industry ($M)	Grand total ($M)
34	481	$1491.5	$1457.6	$2949.1

Source: Adapted from Wessner, *The Advanced Technology Program: Assessing Outcomes* (2001)

2.3.1 *Does US Public Intervention Have a Positive Impact?*

2.3.1.1 Crowding Out/Crowding In: Halo Effect

Most research on the US system has focused on whether or not there is potential crowding out from private sector finance. There is no clear consensus on whether there is, indeed, a crowding-out effect. However, research by Hall, David et al. (1999) suggest that the effect is, at a minimum, negligible for private finance. They also note that there is potential opposite effect of "crowding in." This effect, which is also termed the "halo effect," is thought to be associated with private investors who see the potential awards as a signal of quality and consequently are willing to invest more time and effort in a potential awardee, rather than treat the awardee as an unknown quantity.

There are qualitative differences in awards that need to be considered by potential investors. For example, receiving an SBIR I award may not add additional interest to the VC market. However, if an awardee receives an SBIR III award, this signals to the market that the firm has not only produced a potential product but also that this product is something the US government may wish to purchase in an opening bidding contest.

SBIR III awards may serve to provide high-quality information between investor and entrepreneur. Uncertainty for investors is one of the most negative factors in their decision as to whether to invest in a potential firm or not. If the investor believes the SBIR award system to be of high quality, this removes an important degree of uncertainty.

2.3.1.2 Geographical Diversification

The second important aspect is that in other countries, venture capital markets are not as advanced or geographically disperse as in the United States. Venture capital in other countries is generally centralized in the most concentrated hubs such as in Europe, London, Paris, Milan, or Munich. Other countries also tend to focus more on innovation from medium and large firms than on innovation from small firms. The introduction of an SBIR system could help to lower the sunk costs for potential venture capital, which would allow capital markets to diversify their portfolio into larger percentages of small-firm ventures.

As shown in Table 2.8, the US venture capital market for early stage start-ups rose from 2.6 billion dollars in 1996 to 5.3 billion dollars 12 years later. Indeed, there is a wide diversity of venture capital for a broad range of industries. While there are central clusters of venture capital for specific technologies, such as biotech venture capital in Silicon Valley, there are also venture capital markets spanning the United States. A lack of venture capital outside of the hubs remains an obstacle for economic innovation and activity.

Table 2.8 US venture capital investment, financing stage, industry, and number of companies: 1995–2008 (millions of current dollars)

Financing stage/industry/ number of companies	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
All financing stages	7628	10,840	14,364	20,172	52,016	101,767	39,308	21,250	19,278	22,117	22,922	26,334	30,639	28,077
Seed/start-up	1244	1267	1309	1679	3571	3053	739	327	341	461	893	1194	1330	1494
Early	1694	2614	3430	5389	11,263	24,569	8387	3723	3455	3918	3830	4195	5686	5346
Expansion	3553	5340	7382	9999	28,720	58,138	22,248	12,063	9760	9086	8574	11,417	11,386	10,473
Later	1138	1619	2243	3105	8463	16,007	7935	5138	5723	8653	9626	9528	12,237	10,765
All industries	7628	10,840	14,364	20,172	52,016	101,767	39,308	21,250	19,278	22,117	22,922	26,334	30,639	28,077
Biotechnology	768	1156	1385	1520	2029	4057	3400	3183	3553	4145	3924	4504	5247	4410
Business products and services	177	377	409	691	2791	4560	1031	450	579	396	396	552	709	477
Computers and peripherals	324	383	377	372	897	1596	655	457	373	590	539	532	586	424
Consumer products and services	473	503	738	622	2534	3350	662	228	163	309	304	407	476	437
Electronics/instrumentation	125	193	260	227	282	773	381	314	236	351	438	722	563	574
Financial services	194	329	362	781	2202	4180	1380	338	410	520	918	462	558	526
Healthcare services	448	664	869	926	1368	1352	499	368	222	363	407	381	295	192
Industrial/energy	529	504	696	1407	1508	2479	1067	740	756	775	808	1925	3222	4576
Information technology services	178	430	655	1057	3958	8619	2391	1039	775	737	1063	1377	1707	1812
Media entertainment	910	1074	956	1744	6560	10,299	2312	712	879	965	1149	1624	1962	1884
Medical devices and equipment	627	648	1016	1144	1511	2312	1997	1838	1602	1921	2186	2910	3872	3446

Networking equipment	347	612	937	1360	4259	11,409	5543	2595	1737	1545	1517	1091	1378	735
Other	10	21	56	88	84	45	62	4	0	1	57	8	2	23
Retailing/distribution	314	257	303	609	2805	3067	321	151	65	174	207	201	365	235
Semiconductors	202	299	567	618	1290	3542	2391	1503	1764	2128	1923	2101	2080	1641
Software	1123	2218	3281	4367	10,295	24,012	10,141	5150	4462	5375	4803	4920	5423	5027
Telecommunications	880	1171	1498	2639	7642	16,116	5074	2180	1701	1822	2283	2618	2196	1659
Internet specific	505	1562	2359	4457	23,331	42,233	9848	3577	2388	2875	3336	4336	5176	4871
Clean technology	77	157	144	107	200	577	386	390	263	440	523	1458	2656	4023
Number of companies	1539	2076	2537	2979	4404	6335	3786	2634	2461	2625	2708	3089	3301	3262

Notes: Seed/start-up includes proof of concept (seed), research, product development, or initial marketing. Early includes financing for activities such as initial expansion, commercial manufacturing, and marketing. Expansion includes major expansion of activities or to prepare a company expecting to go public within 6–12 months. Later includes acquisition financing and management and leveraged buyout. Internet specific are companies whose business model is fundamentally dependent on the Internet, regardless of the company's primary industry category. Clean technology comprises companies that focus on alternative energy, pollution and recycling, power supplies, and conservation

Science and Engineering Indicators 2010

Source: PricewaterhouseCoopers/National Venture Capital Association, MoneyTree™ Report (data provided by Thomson Reuters), https://www.pwcmoneytree.com/MTPublic/ns/index.jsp, accessed 23 October 2009

2.3.2 Does US Public Intervention Show Characteristics that Drive Its Positive Impacts?

2.3.2.1 Agreeing on Innovation Targets

US R&D differs from other countries' R&D in several ways. The first difference is simply investment. The United States can target strategic R&D investment on a far greater scale. Specifically, the United States can coordinate at federal, state, and agency levels. For example, to place a "man on the Moon" within 10 years, the United States was able to concentrate its ability on a specific goal at all levels of government. This focus is concentrated from the executive office and allows the United States to have an economy of scale effect when strategically targeting specific innovative goals. In other countries, similar concentration usually requires that multiple large agencies have to deal with a higher level of compliance costs, which also takes time, in order to form a consensus on a particular goal.

The second area of difference is that the United States places an explicit goal of R&D transfer into the commercial market. As shown in Table 2.9, US agencies not only have to allocate 2.5 % of their funding to SBIR but they must also actively seek partners to transfer newly developed technology into the market. Indeed as one notes, all US agencies are active in commercializing their intellectual property for commercial application.

In general, national agencies are not required by legislation, such as the Bayh-Dole Act or SBIR in the United States, to make the necessary and important knowledge transfers. This legislation proved vital for innovative success in the United States and it would be equally in any other context.

2.3.2.2 Creating Innovation Clusters

In addition to the agency spillover, the United States also created technology and knowledge clusters which are now associated with some of the best innovative firms in the field. As shown in Table 2.10, for example, Oak Ridge National Laboratory is a world leader in nuclear energy and has led to a myriad of very successful spillover companies.

These specialized knowledge centers also attract needed venture capitalists to help facilitate these transfers. As one notes in Table 2.10, in the United States most of these federally funded hubs are based in either California or the Washington, DC, area. These consolidated hubs require federal clustering for venture capital markets to move into the area.

2.3.2.3 Coordination of Public Intervention

The United States is considered a world leader in transferring new technology to the market. However, it would be wrong to associate this success with a formula, which can be easily replicated by other countries or regions. The US government is a

Table 2.9 Federal laboratory technology transfer activity indicators, by selected US agency: FY 2007

Technology transfer activity indicator	Total	DOD	HHS	DOE	NASA	USDA	DOC
Invention disclosures and patenting							
Inventions disclosed	4486	838	447	1575	1268	126	32
Patent applications filed	1824	597	261	693	105	114	7
Patents issued	1406	425	379	441	93	37	4
Licensing							
All licenses, total active	10,347	460	1418	5842	1883	339	217
Invention licenses	3935	460	915	1354	461	339	217
Other intellectual property licenses	6405	0	460	4488	1422	0	0
Collaborative relationships for R&D							
CRADAs, total active	7327	2971	285	697	1	230	2778
Traditional CRADAs	3117	2383	206	697	1	184	154
Other collaborative R&D relationships	9445	0	0	0	2666	4084	2695

Notes: Other federal agencies not listed but included in total: Department of the Interior, Department of Transportation, Department of Veterans Affairs, and Environmental Protection Agency. Department of Homeland Security expected to provide technology transfer statistics starting in FY 2008. Invention licenses refers to inventions that are/could be patented. Other intellectual property refers to intellectual property protected through mechanisms other than a patent, e.g., copyright. Total active CRADAs refer to agreements executed under CRADA authority (15 USC. 3710a). Traditional CRADAs are collaborative R&D partnerships between a federal laboratory and one or more nonfederal organizations. Federal agencies have varying authorities for other kinds of collaborative R&D relationships

CRADA cooperative research and development agreement, *DOC* Department of Commerce, *DOD* Department of Defense, *DOE* Department of Energy, *HHS* Department of Health and Human Services, *NASA* National Aeronautics and Space Administration, *USDA* US Department of Agriculture

Science and Engineering Indicators 2010

Source: National Institute of Standards and Technology, Federal Laboratory Technology Transfer, Fiscal Year 2007, Summary Report to the President and the Congress, January 2009, http://patapsco.nist.gov/ts/220/external/index.htm, accessed 6 May 2009. See appendix Table 4-43

unique organization, in terms of scale and scope of its executive legislative powers. The United States also has world leading private and public universities and the sheer ability to drain the best and brightest talent from the rest of the world. These factors represent considerable competitive advantages and must be considered when trying to replicate innovative mechanisms from the United States.

Other countries' systems are far from being able to coordinate on a scale similar to the United States. However, that should not deter them from adopting successful mechanisms from the US innovation model. There are several areas (e.g., crossing the valley of death) where, with proper coordination and efficient funding, other countries could produce innovation which otherwise might not exist.

Table 2.10 R&D expenditures at federally funded research and development centers: FY 2007 (thousands of dollars)

FFRDC	All expenditures	Federal	Sponsoring agency	Location
All FFRDCs	13,820,767	13,396,861	na	na
University-administered FFRDCs	**5,855,193**	**5,654,952**	**na**	**na**
Ames Laboratory	25,254	25,254	DOE	Ames, IA
Argonne National Laboratory	489,684	445,096	DOE	Argonne, IL
AUI National Radio Astronomy Observatory	129,000	128,158	NSF	Green Bank, WV
Fermi National Accelerator Laboratory	337,306	336,927	DOE	Batavia, IL
Jet Propulsion Laboratory	1,717,203	1,717,203	NASA	Pasadena, CA
Lawrence Berkeley National Laboratory	503,775	443,273	DOE	Berkeley, CA
Lawrence Livermore National Laboratory	1,353,980	1,298,044	DOE	Livermore, CA
Massachusetts Institute of Technology Lincoln Laboratory	618,011	613,858	DOD, Department of the Air Force	Lexington, MA
National Astronomy and Ionosphere Center	13,591	13,375	NSF	Arecibo, PR
National Center for Atmospheric Research	144,293	132,375	NSF	Boulder, CO
National Optical Astronomy Observatory	53,608	46,624	NSF	Tucson, AZ
Plasma Physics Laboratory	75,720	75,488	DOE	Princeton, NJ
Software Engineering Institute	80,566	67,657	DOD, Office of the Secretary of Defense	Pittsburgh, PA
Stanford Linear Accelerator Center	231,960	231,960	DOE	Stanford, CA
Thomas Jefferson National Accelerator Facility	81,242	79,660	DOE	Newport News, VA
Industry-administered FFRDCs	**4,780,586**	**4,693,399**	**na**	**na**
Idaho National Laboratory	248,322	235,506	DOE	Idaho Falls, ID
Los Alamos National Laboratory	2,046,260	2,029,056	DOE	Los Alamos, NM
NCI Frederick Cancer R&D Center	339,800	339,800	NIH	Frederick, MD
Sandia National Laboratory	2,031,309	1,974,142	DOE	Albuquerque, NM
Savannah River Technology Center	114,895	114,895	DOE	Aiken, SC

Nonprofit-administered FFRDCs	**3,184,988**	**3,048,510**	**na**	**na**
Aerospace Corporation	36,490	16,930	DOD, Department of the Air Force	El Segundo, CA
Arroyo Center	25,195	25,195	DOD, Department of the Army	Santa Monica, CA
Brookhaven National Laboratory	510,212	491,138	DOE	Upton, NY
C3I FFRDC	46,368	46,368	DOD, Office of the Secretary of Defense	Bedford, MA/ McLean, VA
Center for Advanced Aviation System Development	7290	7290	FAA	McLean, VA
Center for Naval Analyses	99,993	89,721	DOD, Department of the Navy	Alexandria, VA
Center for Nuclear Waste Regulatory Analyses	17,007	16,519	NRC	San Antonio, TX
Homeland Security Institute	25,370	25,370	Department of Homeland Security	Arlington, VA
Institute for Defense Analyses Communications and Computing	59,500	59,500	National Security Agency	Alexandria, VA
Institute for Defense Analyses Studies and Analyses	141,500	141,500	DOD, Office of the Secretary of Defense	Alexandria, VA
Internal Revenue Service FFRDC	7101	7101	IRS	McLean, VA
National Defense Research Institute	38,152	38,152	DOD, Office of the Secretary of Defense	Santa Monica, CA
National Renewable Energy Research Laboratory	190,874	183,812	DOE	Golden, CO
Oak Ridge National Laboratory	1,083,509	1,031,919	DOE	Oak Ridge, TN
Pacific Northwest National Laboratory	851,512	823,080	DOE	Richland, WA
Project Air Force	39,315	39,315	DOD, Department of the Air Force	Santa Monica, CA
Science and Technology Policy Institute	5600	5600	NSF	Washington, DC

na not applicable, *DOD* Department of Defense, *DOE* Department of Energy, *FAA* Federal Aviation Administration, *FFRDC* Federally Funded Research and Development Center, *IRS* Internal Revenue Service, *NASA* National Aeronautics and Space Administration, *NCI* National Cancer Institute, *NIH* National Institutes of Health, *NRC* Nuclear Regulatory Commission, *NSF* National Science Foundation

2.3.2.4 Cost-Efficient Management of Programs for Beneficiaries

The importance to expedite and efficiently turn over potentially highly esoteric SBIR award applications without placing a burden on small firms is imperative for innovative success. Small firms operate on small budgets, usually with just enough cash flow to last from several months to a year. If potential awardees invest their limited resources in an SBIR program application, it is important that they are not burdened by unnecessary costs.

2.3.2.5 University Technology Transfer Mechanisms

In Europe, for example, one of the greatest achievements in the past 10 years was the improvement in the quality of its university research. Costly investment led to increased publications and quality of accepted research. Indeed, one may imagine future scholars reviewing the past 10 years as a period of "European University Renaissance." As shown in Tables 2.11 and 2.12, the EU has now significantly surpassed the United States in terms of journal articles published and is relatively close in terms of top-quality journal citations.

Table 2.11 S&E journal articles produced by selected regions/countries: 1988–2008 (thousands)

Year	The United States	EU	Asia-10	Japan	China	Asia-8	Rest of world
1988	169.97	146.37	50.74	33.86	4.63	12.26	92.29
1989	177.72	153.95	55.85	36.98	5.48	13.39	97.09
1990	181.25	157.92	58.27	38.35	6.10	13.82	99.23
1991	187.12	162.69	61.80	40.66	6.23	14.91	99.11
1992	187.52	171.22	65.48	42.54	6.75	16.19	97.65
1993	190.54	180.66	69.80	44.39	7.60	17.82	96.01
1994	192.93	190.29	74.54	47.07	8.05	19.42	99.11
1995	193.34	195.90	76.18	47.07	9.06	20.05	99.23
1996	193.16	203.95	83.29	50.35	10.53	22.41	101.37
1997	189.75	208.90	87.48	51.46	12.17	23.85	102.36
1998	190.43	214.76	93.80	53.84	13.78	26.18	103.44
1999	188.00	217.19	99.56	55.27	15.72	28.57	105.46
2000	192.74	222.69	106.47	57.10	18.48	30.89	108.55
2001	190.59	220.41	110.90	56.08	21.13	33.68	107.46
2002	190.50	221.72	115.46	56.35	23.27	35.84	110.71
2003	196.43	224.85	125.56	57.23	28.77	39.57	114.88
2004	202.08	230.48	135.58	56.54	34.85	44.20	120.50
2005	205.52	235.09	144.84	55.50	41.60	47.73	124.73
2006	209.24	242.79	157.58	54.46	49.58	53.55	130.66
2007	209.70	245.85	165.83	52.90	56.81	56.12	136.77
2008	198.84	232.94	165.68	47.80	60.98	56.90	130.54

Table 2.12 Share of region's/country's papers among world's most cited S&E articles: 2007 (percent in category)

Citation category	The United States	EU	Asia-10
Top 1 %	1.64	0.82	0.41
2–5 %	6.03	3.87	2.36
6–10 %	6.20	4.64	3.22
11–25 %	14.95	13.04	10.04

As mentioned in previous chapters, a keynote for US innovation, however, is its ability to transform ideas into innovation, i.e., the knowledge filter. Yet, if one of the primary pistons of US growth is found in regions rich with university technology transfer mechanisms, such as Silicon Valley, Route128, and the Research Triangle, an open and important question for the EU remains: how to adapt the European University Renaissance of ideas and transform these significant investments into innovation? If other countries do not implement proper mechanisms such as the Small Business Technology Transfer (STTR), for example, they will be unable to exploit these new and important ideas and may continually lag behind its competitors with better mechanisms of knowledge transfer.

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