SPRINGER BRIEFS IN ENTREPRENEURSHIP AND INNOVATION

Nicholas S. Vonortas
Phoebe C. Rouge
Anwar Aridi *Editors*

Innovation Policy
A Practical Introduction

Springer

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ISSN 2195-5816 ISSN 2195-5824 (electronic)
SpringerBriefs in Entrepreneurship and Innovation
ISBN 978-1-4939-2232-1 ISBN 978-1-4939-2233-8 (eBook)
DOI 10.1007/978-1-4939-2233-8

Library of Congress Control Number: 2014957311

Springer New York Heidelberg Dordrecht London

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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Chapter 1
Introduction

Nicholas S. Vonortas, Phoebe C. Rouge and Anwar Aridi

This short book provides a quick introduction to important aspects of contemporary innovation policy. It addresses a non-specialist audience interested in quickly building background knowledge, getting familiar with the terminology, and getting an overview of core concerns and debates in this area of policy. The book has its origins in a much more extensive report to the World Bank prepared to impart background information to middle- and upper-level policy decision-makers and analysts as well as stakeholders from industry and universities from developing countries prior to engaging in intensive "how-to" policy training. Our audience also includes upper-level undergraduate and graduate students embarking on the study of innovation policy.

The book is intended as a practical guide to selected issues in innovation policy as they relate primarily to economic growth and development. In preparing the material we have assumed no particular knowledge of the subject matter by the reader and only elementary understanding of economics. The book sets up the policy context and then deals with some of the most important issues in the innovation policy sphere today. It references critical readings on each topic but deliberately avoids bogging down the reader with long reference lists.

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N. S. Vonortas et al. (eds.), *Innovation Policy,* SpringerBriefs in Entrepreneurship and Innovation, DOI 10.1007/978-1-4939-2233-8_1

We do not claim comprehensive coverage of all topics related to innovation policy. Rather than providing a lot of detail, the purpose here is to quickly wrap the reader's mind around basic concepts and quickly enable him/her progress to the topics. For instance, whereas we discuss intellectual property protection and standards, we do not delve into technological paradigms and trajectories and the importance of property rights in these. And, whereas we discuss strategic alliances and high-risk finance, we hardly put the two together to deal with innovative high-risk financing networks. Rather than being comprehensive—an impossible task for a single short book—our aim is to distill and provide adequate information in one place that will prepare a diverse audience to march deeper into more specific topics subsequently.

The more nuanced reader with generalist interest in innovation policy for growth and development will find several other important survey-like books in this field in order to expand beyond the present short book. A partial list would include:

- Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds) (2005) *The Oxford Handbook of Innovation*, Oxford University Press.
- Bronwyn H. Hall and Nathan Rosenberg (eds) (2010) *Handbook of the Economics of Innovation*, Elsevier.
- Chris Freeman and Luc Soete (1997) *The Economics of Industrial Innovation*, 3rd ed., MIT Press.
- Vernon W. Ruttan (2001) *Technology, Growth, and Development*, New York: Oxford University Press.
- Gregory Tassey (2007) *The Technology Imperative*, Edward Elgar.
- Christine Greenhalgh and Mark Rogers (eds) (2010) *Innovation, Intellectual Property and Economic Growth*, Princeton University Press.
- World Bank (2010) Innovation Policy: A Guidebook for Developing Countries, Washington DC: The World Bank.

A set of international organizations also produces streams of very relevant reports including among others the Organization for Economic Cooperation and Development (OECD), the World Bank, the United Nations Conference on Trade and Development (UNCTAD) and Industrial Development Organization (UNIDO), and the World Intellectual Property Organization (WIPO).

This book is comprised of six thematic chapters:

Chapter 2: Fundamentals of Innovation Policy for Growth and Development This chapter provides an overview that initiates the reader quickly into the subject of technology and innovation policy. The chapter begins with a short discussion of the models of economic growth to provide a foundation for understanding how economists view, from a macro-economic perspective, the role that technology and innovation play in the economic growth process. It then proceeds to a more micro-level discussion, beginning with the creation of new technologies (invention) and their commercialization (innovation) and spread (diffusion) across the economy. The chapter then returns to the macro-economic level with a discussion of the relationship between technology and international economic competitiveness.

Chapter 3: University Entrepreneurship This chapter deals with a core sector of the Triple Helix: universities. Specifically, it deals with universities through the prism of entrepreneurship and linkages with industry. The creation of new technologies and new industries rests partially on the transfer of new knowledge to industry, through support of academic research and the movement of scientific talent out to the private sector in the form of trained graduates. The discussion addresses the experience of the United States, the country which is still considered by many as the standard bearer in this respect and the example for other countries to emulate. The chapter focuses on major policy actions and related debates during the past three decades or so in order to flesh out the main points of interest in university-industry relations and the role of the government in trying to foster these by incentivizing higher education institutions to become more entrepreneurial.

Chapter 4: Strategic Alliances/Knowledge-Intensive Partnerships This chapter deals with one of the most important developments during the past few decades: the proliferation of strategic partnerships around the world, especially those based on the production, exchange, and/or use of new technical knowledge. There is little doubt of the centrality of such collaborative agreements across all developed countries and the top tier of developing ones (BRICS+). A strong argument can be made that alliances have a critical role to play in the development and market exploitation of new technologies across all industries and especially knowledge-intensive industries such as those for which information and communication technologies, biotechnology and new materials are important. This chapter deals with this very important issue from the point of view of company strategy and consequent policy implications. It provides a practical guide of the issues involved and illustrates through several cases around the globe.

Chapter 5: Clusters/Science Parks/Knowledge Business Incubators This chapter addresses a major strategic topic in the context of innovation policy: clusters and science parks. These two formations can overlap significantly but are still distinct and thus the chapter is divided into two major parts. Part I deals with the broader concept of clusters (geographical agglomerations of industry to exploit specific locational advantages and spillovers). Part II deals with science parks (geographical agglomerations of industry to exploit proximity with universities and major research institutes). The second part also extends to the incubation of small companies. The chapter is sprinkled with many examples of successful and less successful cases from around the world.

Chapter 6: High Risk Finance This chapter focuses on an absolutely critical aspect of innovation: the transfer of an idea from initial concept to prototype and then to the market. A core component of this process is risk financing, that is, the ability to fund emerging business of higher than average risk. Financial systems around the world struggle with this difficult issue which, nevertheless, has been isolated as of critical importance to development and growth. How does a government deal with the lack of "patient" capital? Venture capital? Investment angels? And so forth. The chapter defines the challenge, provides an overview of the various types of finance for various stages of investment, addresses the important topic of market exit, and then goes into the challenges for emerging markets. The chapter then offers available approaches to supporting high-risk finance by the public sector, offers examples from around the world, and closes with policy recommendations.

Chapter 7: Intellectual Property, Standards This chapter deals with two very important framework conditions of contemporary innovation systems: intellectual property protection and standards. Both these issues—left on the backburner for most of the modern history of industrialization—have been elevated to the forefront due to the arrival of the knowledge-based economy and globalization. Countries that want to be important players in the global economy simply cannot disregard them, even though occasionally they may sound less interesting to some policy decision makers. The chapter summarizes the state-of-the-art in our current understanding of these two topics and relates them to economic development.

Chapter 2
Fundamentals of Innovation Policy for Growth and Development

David Feige

2.1 Introduction

This book deals with technology and innovation and their relationship to economic growth. The emphasis is on policy rather than the underlying economics and the book is designed to be accessible to readers who lack a foundation in economics beyond the principles of the subject. The centrality of economics to an understanding of the underlying processes of economic growth, however, necessitates some discussion of the topic. We have attempted to introduce these concepts in a way that is understandable to the lay reader.

This chapter serves as an overview. It begins with a short discussion of the models of economic growth to provide a foundation for understanding how economists view, from a macro-economic perspective, the role that technology and innovation play in the economic growth process. We will then proceed to a more micro-level discussion, beginning with the creation of new technologies (invention), and their commercialization (innovation) and spread (diffusion) across the economy. We will then return to the macro-economic level with a discussion of the relationship between technology and international economic competitiveness.

It is worthwhile first to define some basic terms so that the reader understands the vocabulary used throughout the book. The words “science and technology” are frequently used together but their separate meanings are sometimes lost in the process. Similarly, the terms “technology” and “innovation” are sometimes used interchangeably. For our purposes, *science* is the systematic search for new knowledge. *Technology* is the application of that knowledge to the production process. *Innovation* can be distinguished from technology by understanding that technology is only one way to innovate. Although it is the most common form of innovation in developed countries, there are other forms of innovation including innovations in

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N. S. Vonortas et al. (eds.), *Innovation Policy,* SpringerBriefs in Entrepreneurship and Innovation, DOI 10.1007/978-1-4939-2233-8_2

marketing or organizational form. Other terms will be introduced in the course of this chapter as well.

This book has a strong policy focus. As such, the assumption that underpins its content is that policymakers can intervene (productively) to encourage the production and use of new technologies. While the existence of market failures suggests a useful role for governments, it is true that not all government intervention is helpful and can occasionally be counterproductive. We will attempt throughout to highlight what we believe to be the appropriate role of government in encouraging and accelerating the process of technology creation, commercialization, and diffusion.

2.2 Models of Economic Growth

This section provides an overview of some of the primary economic growth theories and the way they have evolved over time to account for the role of technology and innovation in the economic growth process. It provides context for more policy-oriented sections to follow. We define economic growth as a sustainable increase in GDP per capita. The section will explore neoclassical growth theory; endogenous growth models; and evolutionary models; followed by a brief discussion of the convergence hypothesis.

2.2.1 The Neoclassical Growth Model[1]

The neoclassical growth model, also known as the "Solow-Swan" model, was probably the first modern model of economic growth to explicitly recognize the role of technology as a central driver of economic growth. It is associated most closely with Robert Solow, who observed in 1957 that a large part of U.S. economic growth was unexplained by the contributions of capital and labor, the two factors that characterized earlier models. Solow (1957) attributed this unexplained element to technological change and referred to it as Total Factor Productivity, or TFP (Moses Abramowitz referred to it as "the measure of our ignorance" in recognition of the fact that we have very little understanding of the myriad factors that contribute to it and the degree to which each does so). In Solow's model, only growth in technology can result in sustainable economic growth. Importantly, Solow's model assumes that technology is produced exogenously (outside of the model). We shall see in a moment that this has been a key point of contention with some of the more recent models.

Additionally, the model identified a "steady-state" rate of growth, or the growth rate that a country could theoretically sustain in the long term. "Over-performing" countries, or those above the steady-state rate of growth, would inevitably regress

[1] Sect. 3.1 and 3.2 draw on Greenhalgh and Rogers (2010).

to that rate of growth; while those countries performing at a sub-optimal level (a level below their steady state) would naturally increase their growth rate until they reached that sustainable rate. An important implication of Solow's model, then, is that it suggests that underperforming countries will grow faster than better performing economies do. That is, the poorer a country is (in terms of GDP per capita) the more quickly it would grow relative to wealthier ones. This suggested the inevitability of "convergence", or the gradual catch-up of poorer countries to richer ones.

2.2.2 Endogenous Growth Theories

Solow's model began to receive serious challenges in the 1970s as some of its key assumptions appeared to conflict with observed reality. The first was its assumption that technology was produced outside of the model, which seemed inconsistent with the fact that much invention and innovation is part and parcel of the economic system and is very much determined by the everyday decisions of the economic units in this system. Second, the model continued to under-explain actual observed rates of economic growth. And third, while some countries appeared to be converging others appeared to be diverging from the leading economies. An important set of these challenges coalesced into what is known as the endogenous growth theory (or New Growth Theory), most closely associated with Paul Romer (1986).

Endogenous growth models made three key assumptions distinct from Solow's model. First, they assumed that the production of technology is endogenous (internal), rather than exogenous (external), to the model. That is, they recognized the explicit role of economic units such as firms in the production of new technologies. Second, they assumed that knowledge could "accumulate"; that knowledge is a cumulative process that could be maintained and added to over time. Finally, they also assumed that knowledge "spills over"; that knowledge produced by one firm may be useful to others. Further, this process is inter-temporal; that is, firms can benefit from knowledge that was produced by other firms at an earlier point in time.

The endogenous growth model has important implications. While Solow's model assumed that capital has diminishing returns (that is, each additional dollar of capital results in a lower amount of additional output, everything else constant), in Romer's model, although individual firms may face diminishing returns to capital, the economy as a whole does not. This suggests that growth is possible in the long run and contrasts with Solow's prediction that growth could not be sustained at levels above their "steady state". While other variations on the endogenous growth model exist (see, for example, Lucas 1988), Romer's remains the most widely known.

2.2.3 Evolutionary Economics

Many of the ideas embodied in the endogenous growth models had already been discussed previously in a loose coalition of economic thought called evolutionary economics, such as the ideas on the nature of knowledge, the way it accumulates, and the possibilities for systemic learning and for increasing returns. However, evolutionary economics also challenged some of the basic concepts of neoclassicism which also continued in endogenous growth and is thus considered a separate (and challenging) school of thought.

Evolutionary economics is inspired by biological processes and focuses principally on two ideas (Verspagen 2005). The first is that firms are "chosen" by the market based on their ability to adapt to changing circumstances. The second is that innovation simultaneously (and continuously) introduces novelty into the system, effectively creating a "moving target" that firms need to adjust to. A third can be added regarding the way firms make decisions: rather than maximizing profits (which requires a huge amount of information), they develop and follow "sticky" routines and maximize "satisfying" behavior (i.e., make their owners feel happy with their investment). The constant interaction between the ever-changing system and the firms that inhabit it determines the "winners" that emerge. Importantly, these outcomes are difficult to predict. One strain of evolutionary economics postulates that technological development (and therefore economic growth) is dictated largely by technological trajectories or paradigms, which determine the parameters within which technology will advance for extended periods of time. These provide the context for specific innovations which "cluster" in time because a series of incremental innovations closely follow a radical one. The largest and most significant of these innovations may be so-called General Purpose Technologies, or GPTs, that are characterized by their broad application throughout the economy, such as ICT, biotechnology, or new materials.

There are two key distinctions between evolutionary economics and endogenous growth theory. First, endogenous growth theory assumes that firms are aware of the entire range of potential technologies and as such can "jump" from one technology to another as technologies prove themselves to provide a more profitable set of outcomes. Evolutionary economics, on the other hand, suggests that firms tend only to be aware of technologies very close to their current technology and are thus not necessarily able to take advantage of new technologies as they present themselves. Second, endogenous growth theory assumes "weak uncertainty" associated with policy choices (that is, the range of outcomes related to a policy choice are known but the specific outcome that will result is not); while evolutionary economics adheres to "strong uncertainty" (that policymakers are not even aware of the full range of outcomes). Therefore, while endogenous growth theory assumes that a series of policy levers can be pulled to result in a fairly predictable outcome, evolutionary theory suggests it is much more difficult to know what the outcome of specific policies will be.

2.2.4 The Convergence Hypothesis

We close this section with a brief word on the convergence hypothesis. It was mentioned earlier that Solow's model predicts convergence; but that we observe a combination of convergence and divergence. That is, some countries appear to be converging with (catching up to) the leading economies, while others appear to be diverging from them. A concise characterization of the convergence hypothesis was given by Baumol et al. (1989). When the productivity level of one or more countries is substantially superior to that of a number of other economies, largely as a result of differences in productive techniques, then laggard countries that are not too far behind the leaders will be in a position to embark upon a catch-up process. Many of them will actually do so. The catch-up process will continue as long as the economies approaching the leader's performance have a lot to learn from the leader. As the distance among the two groups narrows, the stock of unabsorbed knowledge will diminish and even approach exhaustion. The catch-up process will then weaken or even terminate unless some other unrelated influence comes into play. Meanwhile, those countries that are so far behind the leaders that find it impractical to profit substantially from the leaders' knowledge will generally not be able to participate in the convergence process at all. Many such economies will find themselves falling further behind, widening the gap between wealthy and poor nations.

The convergence hypothesis was empirically tested and debated over the years. According to Baumol et al. (1989), a country's ability to "converge" with leading economies is a function of (1) capital accumulation, (2) technological innovation, and (3) imitative entrepreneurship (which borrows ideas from abroad and adapts them to local circumstances).

Abramowitz (1986), on the other hand, highlights the role of social capabilities (effective institutions, including incentives and markets) in determining which countries are best able to close the gap (converge) with countries at the technological frontier. He adds to social capability the importance of "technological congruence", that is, the transferability of the leader's technology to follower countries. Essentially, countries that have developed sufficient capabilities and technological congruence are able to close the gap with the leaders due to the fact that they are able to copy and absorb the technologies the leaders have produced. As the stock of unabsorbed knowledge and technology shrinks, the pace at which convergence happens slows until it eventually comes to a halt as there are no more technologies to copy. (At that point, countries that have caught up can continue increasing their growth rate above that of other technological leaders only by producing their own new technologies). Those countries, however, that lack the capabilities to "understand" and therefore copy and absorb the technologies produced by the leaders, will fall further behind, resulting in divergence from the leaders.

Importantly, the convergence hypothesis predicts a different set of outcomes from those produced by Solow's model. While Solow assumes that convergence is inevitable, convergence theory suggests that it is not; and that good policy can play an important role in determining whether a country takes the path of convergence or of divergence.

2.3 Technology Creation (Invention)

We have now provided some context for the importance of technology in the economic growth process. We proceed in the next three sections to a discussion of how the growth of technology is nurtured. This section focuses on the creation of new technologies. We look first at the mechanics of technology creation. This is followed by a discussion of the rationale for government intervention in the support of research; and concludes with two sections that look more closely at issues of specific interest to policymakers.

2.3.1 The Research Chain

The process of technology creation is often divided into three stages: basic research, applied research, and development (although in reality the lines between the three are blurred). *Basic research* is distinct from applied research in that it is conducted without consideration for a specific application. *Applied research*, on the other hand, is undertaken with a specific need in mind. *Development* is the design, construction, and testing of prototypes of new products and processes. Research is critical because it is the foundation for technology (which, it will be recalled, was defined in Sect. 2.1 as the application of new knowledge to the production process). Technology, in turn, is central to productivity growth, as discussed in Sect. 2.3.

2.3.2 Economic Arguments for Policy Intervention in Research Activity

Most arguments for public intervention in research relate to the more basic and generic aspects of research; as the government is generally considered to be too far removed from the market to play a useful role in applied research.

There are two primary economic arguments that justify public intervention in research activity. The first rests primarily on the theory of *market failures*. This argument suggests that:

- The social returns related to research activity outweigh private benefits, implying that private sector actors are likely to under-invest in research; and
- A high level of uncertainty characterizes R&D and innovative activity, which can be only partly insured.

In addition, market failures can arise due to the fact that certain investments can be made only at significant scale; and as a result of information asymmetries between the parties conducting research and those funding it.

The second economic argument is based on *system failures*. One case of this is when introduction of an initial technology leads to "lock-in" along a sub-optimal technological trajectory—such as, arguably, fossil fuels today. A second case, discussed in greater depth in Sect. 2.6.4.2, relates to the need for coordination among institutional actors in order to promote the diffusion of innovations. A third case in which the government can play a useful role is in making strategic R&D investments both within technology cycles and in managing the transition from one technology life cycle to another. In addition, public intervention can also be important in developing human capital for the purpose of promoting absorption of technology.

2.3.3 Issues of Interest to Policymakers

2.3.3.1 Intellectual Property Rights (IPRs)

One of the most widely discussed policy issues with respect to the creation of new technologies is that of intellectual property rights, or IPRs. IPRs encompass patents, trademarks, copyrights, and trade secrets; these are discussed more extensively in Chap. 7 of this book. We will focus briefly here on patents. Patents in effect grant the inventor a temporary monopoly, thereby allowing them to capture all of the economic benefits from their invention over a limited period of time; in exchange for the inventor's agreement to put all knowledge related to the invention into the public domain. The patent system is therefore an attempt to solve the appropriability problem addressed above.

Several concerns have been raised, however, with respect to the patent system. One relates to the duration of patents and whether it should be uniform across sectors and technologies given the great differences among them. A second involves questions about whether the exercise of some of the rights associated with owning a patent may in fact discourage, rather than encourage, invention. One example is the practice of obtaining patents (with no intention of using them) for the knowledge surrounding an invention a firm currently holds a patent to, thereby preventing other firms from "inventing around" the patent that the firm hopes to exploit. A third issue concerns the cost of the patent system and whether that disproportionately benefits larger firms relative to smaller ones. A fourth involves the length of time necessary to obtain a patent, which may make the technology to be covered by the patent obsolete by the time patent approval is granted. Finally, lax IPR systems in many developing countries have also raised criticisms from more developed countries. In many cases these have been established specifically to promote the diffusion of technologies (discussed in Sect. 2.5) in countries that lack the capacity to produce leading-edge research; but this remains an ongoing subject of controversy.

It is also unclear to what extent patents are central to the decisions of firms to produce (applied) research. Research shows that firms outside of the pharmaceuticals and chemicals sectors rely on patent protection to only a very limited extent (or not at all) to protect their inventions,[2] preferring instead to establish first-mover advantage or the development of complementary capabilities to create a market

[2] Mansfield's work (referenced in Cohen 2010, pp. 182–183)

position that cannot easily be imitated. Firms also in some cases choose not to patent in order to avoid having to put knowledge into the public domain (preferring to resort to trade secrets instead).

2.3.3.2 R&D Composition

Another (often overlooked) issue of interest to policymakers is the composition of R&D spending. Many countries have attempted to target an "optimal" level of R&D spending (3 % of GDP, which was chosen by the European Union in their 2020 growth strategy,[3] seems to be a particularly common target for developed economies, although Korea and a few others have higher stated targets), but have neglected any attention to the split between basic and applied research spending. As noted earlier in this section, while applied research is the basis for products and services that can be commercialized in the near future, basic research plays a critical role in producing the foundation for the technologies that will drive competitiveness in the future. The amount of funding devoted to applied research (most of which is funded by companies) relative to basic research (most of which is funded by governments) typically increases as countries develop. However, there are frequently voiced concerns that insufficient resources are being devoted to basic research activities, thereby potentially compromising a country's future competitiveness. Of additional import is the destination of R&D funding; whether it is oriented toward defense application, for example, or designated for uses that are more likely ultimately to have commercial application.

2.3.3.3 Non-Linear Research Models

We have mentioned that the neat division of research activity into basic research, applied research, and development is an oversimplification of the way that new technologies are developed. This is typically referred to as the *linear model*, and implies that the process of technology creation occurs in a predictable order. In reality, the process is often more iterative than linear. The publication of *Pasteur's Quadrant*, by (Stokes 1997) epitomizes this thinking; calling into question the linear model (basic research leads to applied research which in turn leads to development, production and marketing of new products) while suggesting that the process involves a stronger feedback mechanism (from the market to research) than the linear model envisioned and could be initiated at multiple points in the "research chain". This fact has important policy implications as it suggests that governments will need to strike a balance between "supply-led" policies (in which R&D funding is typically driven by the missions of public organizations) that characterize the linear model and "demand-led", or user-driven, policies, such as those promoting market innovations, that recognize that the end markets play an important role in informing the research that is conducted.

[3] As cited in Albu (2011).

2.3.4 Policy Tools Available to Support Basic Research

Governments can tweak the intellectual property system to obtain desired outcomes; for example, the Bayh-Dole Act in the U.S., which granted the rights to intellectual property produced by universities with federal funding to the universities themselves, has probably incentivized universities to produce more research of value than they might have in its absence (more on this in Chap. 3). However, governments have other tools at their disposal as well. We will mention two; direct support to R&D and tax incentive programs.

Direct support (generally in the form of grants and contracts) ranges from about 20% of total research expenditures in East Asian countries such as Korea and Japan to up to 50% in select European Union countries (the U.S.'s federal share is about 33% of total research expenditures) to higher shares in countries like Brazil (Steen 2012). Much of the public funding in developed countries tends to be directed to universities, which, for example, conduct over half of all basic research in the U.S. Such direct funding for research offers policymakers the advantage of being able to choose where the funding goes while still keeping at some distance from the market.

An alternative to direct support is indirect support through the provision of tax incentives to companies. Such incentives provide matching funds to companies for every dollar of research that they conduct; or for every dollar of research they conduct above a certain baseline (usually determined by past R&D investments by the company). Tax incentives are controversial because of the difficulties associated with linking them to actual increases in company R&D spending. Most research suggests that there is approximately a 1:1 ratio between government spending and research funding allocated; that is, companies increase their total R&D spending by, on average, exactly the amount they receive from the government; which may seem an inefficient subsidy mechanism in catalyzing additional R&D investment.

An additional policy option available to governments is the support of collaborative research partnerships. These partnerships may take the form of public-private arrangements (such as those between governments and private companies) or private-private arrangements (which encourage companies to work together, often through strategic alliances or joint ventures, to produce basic research). This is the subject of Chap. 4 of this book.

2.4 Commercialization of New Technologies (Innovation)

We now turn to a discussion of the commercialization of new technologies, typically the idea associated with innovation. Only a small percentage of all inventions actually become innovations; that is, very few inventions actually find commercial application. Most research suggests that only about 2% of all patents find commercial use. As not all inventions are patented, this is only a representative figure; but does provide some sense of the limited number of new technologies that are created that actually make it to market. Because of this, it is important to understand the dynamics of the commercialization process.

2.4.1 Commercialization and Large Firms

Schumpeter, J. (1942) and his followers at one time asserted that large firms are more capable of generating innovations than small firms are. While extensive research since then has shown this to be inconsistent with the evidence, large firms do play a very important role in commercializing technologies in certain industries, including for instance highly capital-intensive industries such as pharmaceuticals and chemicals and industries requiring the integration of complex products such as automobiles, aircraft, and military equipment. Possessing access to many resources, large firms account for the majority of absolute spending on R&D in the US. In addition, large firms are also the source of numerous spin-offs (discussed in Sect. 2.4.2), thus playing a central role in the innovation ecosystem.

2.4.2 Commercialization and Entrepreneurship/Small Firms

Entrepreneurship was initially largely ignored in discussions of national systems of innovation (discussed in Sect. 2.6.4.2) but has, in the last decade, become a priority in policy circles. Of most interest for this book is the category of entrepreneurs we refer to as *growth entrepreneurs* (also referred to as "opportunity entrepreneurs"), which we define as individuals or teams of people who exploit a previously unidentified or unexploited business opportunity. We distinguish this group from *necessity entrepreneurs*, most commonly found in developing countries, who have turned to entrepreneurship as a livelihood only in the absence of other job opportunities. Within the category of companies set up by growth entrepreneurs, the most important sub-set is R&D-intensive companies. In developed countries this group contributes disproportionately to job creation and innovation and is therefore of great interest to policymakers. Only between 2–4 % of all small and medium sized enterprises (SMEs) can be classified in this group at any point in time. The entire "Research Stairway", and the percentage of firms that fall into each category of research intensity, is illustrated in Fig. 2.1.

Another, largely overlapping, sub-set of companies set up by growth entrepreneurs is the so-called "gazelles", those enterprises that have demonstrated sustained, above average growth in profits. According to a recent report, only about 4 % of respondents fell into this category; but accounted for about 40 % of new job creation in the United States (Endeavor 2011).

While entrepreneurial activity has frequently been attributed to the somewhat mystical qualities of a few gifted or creative individuals, the reality is that it is driven by the interaction of these individuals with the system within which they operate. Thus, the concept of "National Systems of Entrepreneurship" (Acs et al. 2013) has arisen in recognition of this systemic element to the "creation" of entrepreneurs. This recognizes that policymakers have a role in creating an environment supportive of those individuals who have entrepreneurial aspirations, a subject that will be discussed in greater depth in Sect. 2.4.3.

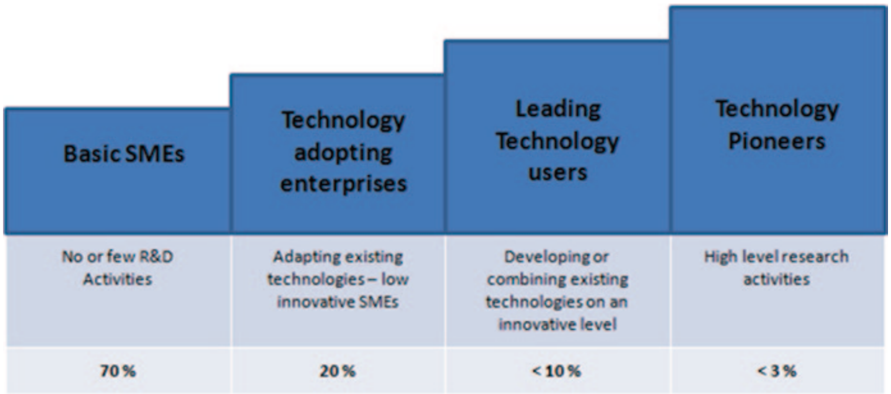

Fig. 2.1 The research stairway (EURAB 2004)

Entrepreneurs can arise, of course, in any industry. Within the context of our discussion of technology and innovation, we are particularly interested in the role that entrepreneurs (and small firms) play in commercializing new technologies. In line with Schumpeter's hypothesis with respect to innovation and firm size, it was at one time believed that large firms were more innovative than small ones. However, more recent research suggests that, although large firms have an advantage innovating in certain industries (as mentioned in Sect. 2.4.1) small firms are, on average, disproportionately responsible for innovation as a whole (Acs and Audretsch 2001). Their relative advantage seems greater when it comes to radical innovation.

They do so in primarily two ways. One is by commercializing research performed in universities; this may happen either when an inventor decides to commercialize his/her own research or through a licensing arrangement. The second is through "spin-offs" from existing firms; a common phenomenon is that an entrepreneurial individual produces an invention within the context of a larger firm to which they assign more value than the firm itself does. In such cases, the entrepreneur may leave the firm, taking their invention with them, and commercialize it under the auspices of a new company (Auerswald and Branscomb 2003). Such practice has been, in fact, institutionalized in certain large companies which sense a window of opportunity on the one hand—spin-off firms that may succeed may be folded back into the corporation later on—while dissipating internal conflicts on the other. In this way entrepreneurs play a key role as conduits of knowledge spillovers, addressed in our discussion of endogenous growth theories in Sect. 2.2.2. While several large companies are attempting to set up innovative units internally to stem the flood of talent leaving the firm and to capture more of the value of such innovations as they come online, such efforts have met with mixed success.[4]

[4] The early example of Xerox's PARC and the current Skunk Works of Lockheed Martin are cases in point.

2.4.3 Policy Interventions Supporting Entrepreneurship and Small Businesses

The focus of policy with respect to commercialization has focused primarily on support to entrepreneurship and small businesses in recognition of their central role in the innovation process. We will touch on a few support mechanisms here; including (1) financing and technical assistance programs (often provided through science parks and business incubators), (2) government procurement, and (3) National Systems of Entrepreneurship.

2.4.3.1 Finance and Technical Assistance

Financing for small enterprises has long been of interest to policymakers. Particular attention has been paid to the so-called "valley of death" that frequently engulfs small enterprises between basic and early applied research, on the one hand, and initial innovation and commercialization, on the other. This refers to the funding gap that exists that is not addressed by either the typical public sector programs supporting research, by angel investors, or by venture capital; thus resulting in the vast majority of small business failures. This subject is more thoroughly covered in Chap. 6 of this book, but the Small Business Innovation research (SBIR) program in the United States is a well publicized attempt by the public sector to address it. The SBIR is generally regarded as a fairly successful model for financing early stage innovation and has been adopted by several countries around the world. Technical assistance programs are another form of non-financial support and may include basic business skills training, help with marketing or product development, or linkages to domestic or export markets. These services are often provided in the context of a business incubator, which provides access to both financing and technical assistance in addition to physical space for the enterprise to operate.

2.4.3.2 Government Procurement

Government procurement is another, probably underutilized, tool that governments have at their disposal to encourage innovative activity among small firms. The military has often played an important role in sourcing leading-edge technologies that ultimately found commercial application, especially in developed countries (semiconductors is a widely cited example); and much of this work was contracted through small businesses. Small firms can similarly play a role in other, non-defense industries through set-aside grants designed to source innovative products or to source technologies specifically from small firms.