The Significance of Innovation

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Abstract: Innovation is fundamental to economic growth. This chapter provides an introduction and overview of innovation and its relationship to economic growth. Firms, industries and countries compete on the basis of innovation. A critical issue is the nature of the relationship between investments in resources, like R&D and realized innovative output and how innovation subsequently affects performance in terms of economic growth. This chapter frames these issues, provides definitions of the various types of innovation and show how innovation and its economic impact is measured. Drawing on recent advances in the literature, the chapter provides an introduction to how economists study innovation, setting the stage for subsequent chapters.

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Innovation is fundamental to economic growth and development. The ability to create economic value by introducing new products to the market, redesigning production processes, or reconfiguring organizational practices is critical to competitive advantage and growth for firms, industries and countries. The question then becomes how to best organize resources to create, diffuse and sustain innovation and, moreover, how to leverage investments made in science and technology, research and development and related capabilities with the ultimate goal of reaping rewards in terms of wealth creation and increased standards of living.

The purpose of this chapter is to describe how economists think about and define innovation and to clarify the role of innovation in economic growth and development. Economic growth is the traditional purview of macroeconomists yet innovation is fundamentally about microeconomics. Sound fiscal policy and stable macroeconomic conditions are certainly important to economic growth but microeconomic concerns such as the role of government to promote innovation relies on addressing market failures that inhibit the accumulation of knowledge and aligning incentives for economic agents to commercialize that knowledge and realize economic value.

Economic Growth and Innovation

Economic growth is most commonly measured using changes in the total value of goods and services produced by a country's economy or what is know as Gross Domestic Product (GDP). Of course, since the size of countries varies this number is adjusted for the size of the population which provides a crude measure of the average individual's well-being. Figure 2.1 presents GDP per capita estimates for several countries for comparison. GDP per capita is highest in the United States compared to any of the other major industrial nations shown. The consensus is that these differences in levels and in trends is driven by increased productivity that comes from innovation and technological change.

The study of innovation and economic growth began in earnest in the late 1950s with the work of Robert Solow (1959) for which he subsequently was awarded the Nobel Prize. Of course, like any idea that gains currency the foundations had been provided by earlier scholars, notably Joseph Schumpeter (1934, 1939, 1942). What was important about Solow's work was that he empirically demonstrated that 87% of economic growth in the American economy from 1909 to 1949 was accounted for by an unspecified factor or residual that he described as technological change. Other studies have refined these estimates and provided more elegant theoretical models. Most importantly, as a point of departure, the basic results hold and have been replicated for other countries: the largest single factor explaining economic growth is not increases in factor inputs but the ability to extract greater economic value from advances in science and technology. The ability to extract economic growth from advances in knowledge is the essence of innovation.

Yet Solow's models treated technological change as exogenous–something that was outside of the model and thus not subject to economic forces. This is not very satisfying [say what the models missed/ignored/could not account for] and since we expect that economic growth should be a function of factors that we can describe, enumerate and model. Ever since then, economists have focused on trying to understand the underlying economic attributes of technological change, specifically innovation in new products, processes and organizational forms. While innovation is important to the performance of countries harnessing the potential of innovation is the domain of microeconomic and there is an increased acceptance of the need to understand innovation as a processes that relies of individual agents, be they firms or individuals, who recognize and respond to new opportunities, organize resources and add economic value and increase productivity.

Clarifying Terms

When an issue is significant the popular discussion may easily become muddled, terms may be used interchangeably and without precision and as a result the debate becomes superficial. To avoid this, a series of definitions that discriminate between the components of innovation will be provided in order to advance the discussion and enrich the choice of policy options.

In daily conversation, terms like *invention* and *innovation* as well as *science* and *technology*, among others, are often used interchangeably. However, for academics and policymakers there are important distinctions between these terms and these distinctions give each term a unique meaning and enrich discussion. Invention is about discovery and the creation of something novel that did not previously exist. Innovation, on the other hand, carries invention further with the commercial realization of the value of the invention or the receipt of an economic return. This is a subtle but important distinction. Thus, patents, the legal protection of an idea reveals an invention while, for example, the marketing and consumer acceptance of a new drug is evidence of an innovation.

Commercialization is the process that turns an invention into an innovation and involves defining a concept around who is willing to pay for the new idea, what attributes they value and how much they are willing to pay for the added value. Through commercialization economic value is realized from new ideas and inventions. The economic profits earned are the rewards. Figure 2.2 demonstrates the weak relationship between economic growth and patenting for the same countries previously considered in Figure 2.1. While patenting measures invention, ccommercialization requires the additional steps of translating inventions into consumer needs and product markets. At its earliest stages, before applications are easily described or generally appreciated, realizing the potential of an invention requires a sophisticated understanding of consumer needs, existing markets for product innovation and factor inputs. Commercialization, even when ideas are abundant, may not be completed because outcomes are highly uncertain and risk aversion may cause projects to be delayed or abandoned. Policy mechanisms such as R&D tax credits or stock options decrease costs and may mitigate the inherent risk of innovation. Venture capital investment, where the investors are knowledgeable about the science and the potential market may also serve to reduce uncertainty.

Realizing the commercial benefit of innovation relies on a variety of inputs. The most notable knowledge input is embodied in skilled human capital, scientists, engineers and managers who appreciate and can implement new ideas. *Entrepreneurs* are the individuals who organize resources to create value from commercialization (see Thurik, Chapter 3). Entrepreneurs are typically associated with new firm start-ups, and individuals who work in large firms are sometimes known as *intrapreneur*, people who work in the public sector or in non-profit organizations are often referred to as *'social* *entrepreneurs'*. Whatever the nomenclature, these terms demonstrate the ways individuals act as agents of change in economic systems.

Science, in a broad sense, is the unfettered search for knowledge for the sake of understanding. That search is based on observed facts that may be replicated through experimentation or theory. Thus, science begins with conventional preliminary conditions and searches for some unknown results to address fundamental questions related to hypothesis about the world. The process of investigation is known broadly as research and research may be *basic* with the intention of advancing science or *applied* with the orientation towards some practical end. These are two ends of a continuum of problem solving as basic research suggests avenues of inquiry that are advanced by applied research. Likewise, research is enriched, made more complex and significant as applied work creates the need for more theoretical work and suggests new avenues for further basic research. In addition, and most critically, while science is classified by disciplines that define traditions of inquiry, and scientists are trained within these specific traditions, applied problem-solving frequently creates the need for multidisciplinary teams or even creates new disciplines to colonize the frontiers of knowledge. Examples would be the rapidly evolving fields of biochemistry and biomedical engineering or the emerging field of nanotechnology.

In contrast, industrial *Research and Development* (R&D) is the systematic augmentation or deepening of knowledge by applying it to some practical problem or new context with the idea of generating a commercial return. While science is typically conducted by universities and institutes of higher learning, R&D is typically conducted by private firms. An important distinction is that private firms have a responsibility to earn returns for their shareholders. In general, the more basic the science involved in a research project the more difficult it is to appropriate the resulting returns. This is due to particular characteristics of the knowledge that research creates. A variety of government incentives and public-private partnership programs have evolved over time from government's desire to steer private investment towards more basic types of scientific activity and to stimulate the development of new technologies that private firms would not consider attractive investments in the absence of some incentives such as direct grants, R&D subsidies or other programs that encourage firms to conduct projects with universities or government laboratories (see Henrekson, this volume).

Knowledge has characteristics such as being nonrival and nonexcludable that classify it as a public good. *Nonrival*, in the economists' terminology, indicates that one person's use of knowledge does not impede another's use of it. Consider the example of a mathematical formula. Knowledge is created when the formula is first derived and formal proofs are demonstrated. The result is most likely a scholarly publication which would codify the knowledge, rendering it easy to diffuse and put into practice. Once the formula is known, the fact that one scientist uses it does not diminish its usefulness or utility to other scientists. In fact, the value of the formula may actually increase as a result of its more diffuse use and acceptance. Thus, knowledge, once created, is nonrival in that many economic actors may enjoy it simultaneously. *Nonexcludability* refers to the fact that once knowledge is discovered it is difficult to contain or to prevent others from using that knowledge. Once an idea is known it frequently seems obvious to others and can be simply replicated at what is known as zero marginal cost.

As a result of these two conditions, the social value of knowledge is greater than the value that the creator may be able to capture, a classic case of an externality. Private firms are likely to under-invest in knowledge production since the returns to the firm are smaller than the returns to society. Patents and copyrights, which extend property rights to knowledge and ideas, are one way, although imperfect, to create markets for the use of new ideas.

Innovation is subtly different from *technology*, which is the embodiment of knowledge into a physical form. *Technological change* is the rate at which new knowledge is put into physical forms and diffused for use in the economy. Major technological advances, such as the steam engine or microprocessors are known as *general purpose technology* as they have broad applications and productivity-enhancing effects in a number of different sectors. As a result, general purpose technologies induce dramatic economic changes by creating innovation that rejuvenates existing sectors and, in the process, create new industries and services. A historical example is the steam engine, the Internet is a more recent example. The Dot-Com bubble notwithstanding, the Internet has fundamentally changed the way business transactions take place, creating efficiencies and productivity growth for existing firms as well as new opportunities for entrepreneurs. Alan Greenspan attributes the expansion of the Information Technology (IT) sector as accounting for at least one-third of the total growth of the United States' economy since 1992. In 1999, the IT sector became the largest commercial sector in the U.S., with job growth six times the average rate.

Yet it is important to remember that innovation also encompasses incremental improvements to existing products or processes. Indeed, the vast majority of innovation may be attributed to minor improvements, adjustments and refinements to existing products, manufacturing process and organizational practices. While not particularly glamorous these activities add economic value and, in sum, provide a basis for sustained competitive advantage. In addition, while science is important to innovation, new ideas are frequently suggested by individuals who work on the shop floor, who use products and who supply machinery or materials. Indeed, innovation spans the spectrum of industrial activity. The view that innovation is limited to new science-based or so called high technology industries is a myopic as it ignores the equally transformative nature of innovation in existing mature industries that are already in place. Consider Proctor and Gamble's new product innovation, the *Swiffer,* which revolutionized household floor care in the very mundane product category of brooms and mops. Within six months of introduction, *Swiffer* had captured one-quarter of the market, the total size of which was estimated at $436.5 million in 2002. Thus, innovation may be profitable in mature industries.

As mentioned earlier, *economic growth* is, most simply, increases in wealth as measured by indicators such as Gross National Product (GNP) or Gross Domestic Product (GDP) for countries. For sub-national or local jurisdictions, increases in employment or in the tax base are a measure of growth. The corollary for firms is output measures such as sales or profits or market share. In contrast, *economic development,* in the case of a country, is associated with structural evolution such as the development of industries that create higher value-added activities. An example of structural transition for a country is the evolution from an economy dependent on agriculture to one with substantial manufacturing and presumably a large share for export. Most critically, causality between economic growth and economic development is uni-directional: while economic development likely leads to economic growth, continued economic growth does not necessarily imply economic development. What is needed for economic development is the addition of new infrastructure and complementary human capital. While new ideas and innovation may guide industry evolution, government as an agent of collective action guides economic development.

The corollary to economic development for firms is the evolution of the product line towards more sophisticated, higher value added products as, for example, Intel became a microprocessor firm instead of a semiconductor manufacturer. Andy Groves, in a book provocatively entitled *Only the Paranoid Survive,* describes how Intel recognized that it couldn't compete with Asian firms in the DRAM market and instead strategically moved into the more knowledge intensive and profitable product line of integrated circuits. To succeed at such a transition requires a firm to recognize new opportunities and develop new capabilities. Many firms do not make this transition in what has become widely popularized through Clayton Christensen (1992) as the *Innovator's Dilemma*–where successful firms become captive to their customers and existing markets and fail to recognize that radically new disruptive technologies are changing market opportunities.

In simplest terms, a country's economy is the sum of the collection of firms located there. The fortune of the firms and their respective industries will determine the growth and development of the country's economy. Firms will innovate when there is a profit incentive to do so, but government has a significant role in both providing incentives and correcting market failures. Our emphasis on policy underscores the role of government in promoting commercialization.

The Role of Government in Innovation

Like firms, governments are socially constructed entities that can raise funds, organize resources and live on in perpetuity or at least do these things better than individuals can. Following this logic, government is a legitimate tool by which individuals can further their shared interests by acting in common. Certainly, governments have more complex objective functions overall than do firms. However when we think about economic growth and development specifically within the context of innovation and industrial competitiveness, the analogy is instructive. For firms, the overarching goal is to gain and maintain competitive advantage, which translates into above average returns for shareholders. For government, the shareholders are citizens.

For firms, the way to achieve competitive advantage is to create a competitive strategy that is consistent with trends in the firm's industry and appropriate to the firm's resources and capabilities (Porter 1996). Feldman and Martin (2004) argue that governments may engage in a similar exercise that considers the unique and not easily replicated assets, resources and skill set contained in a jurisdiction and the position of the jurisdiction relative to the hierarchy of cities in the regional, national and world economy.

At the national level, it will be increasingly important to understand the role of individual cities or regions in constructing competitive advantage and economic growth (see Scott this volume). If a nation is comprised of individual jurisdictions that each attempt to attract the currently fashionable industries (e.g. biotechnology or nanotechnology) and compete against one another, then the overall nations' prosperity potential may be diminished. Just as there is multiplicity of outcomes of corporate strategy, there are likely to be many different models that emerge with respect to how government and firms may work together to foster innovation and economic growth.

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Table 2.1: Real GDP per Capita for Selected Countries, 1970-2001
(PPPs of 1995 USD)
Source: OECD, Statistical Compendium via Internet 2003-10-09 (National Accounts Vol. 1) and Statistical Compendium via Internet 2003-10-09 (OECD Economic Outlook).

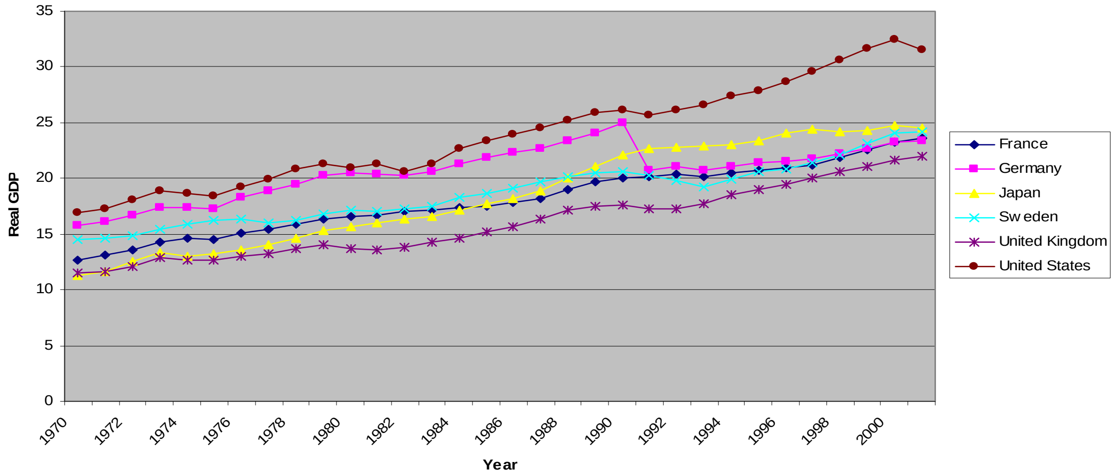
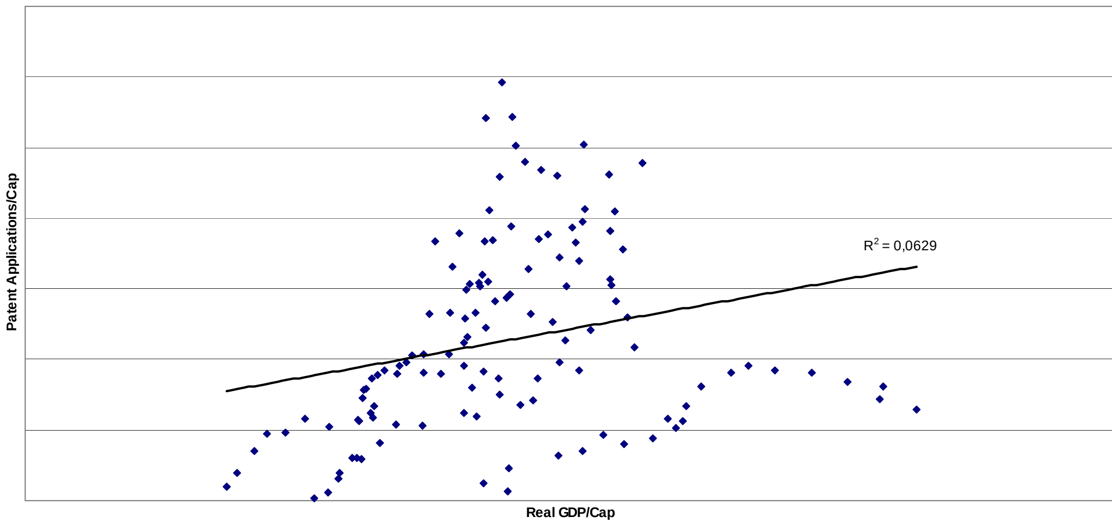


Figure 2.2

Correlation between Real GDP/Cap and Patent Applications/Cap. 1981 - 2001.



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