1-1-2007

Innovation and National Economic Strategy

Andres C. Salazar

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Andres C. Salazar, Northern New Mexico College, Espanola, New Mexico, USA

ABSTRACT

In the formulation of a national economic policy today the need to compete in a global knowledge economy has been recognized. The importance of the knowledge services sector now rivals that of materials and products and their associated processing, manufacturing and distribution sub-sectors. A policy component common to both knowledge services and businesses handling tangible assets is a country's investment and support for innovation as part of a national science and technology (S &T) strategy. Innovation can play a major role in creating new business opportunities, in retaining and perhaps expanding current business dominance, and in transitioning a country's assets to address changing global market needs. Policy components that can be included in an investment model of innovation include direct funding, tax incentives, purchasing, infrastructure investment and trade restrictions. The process flow of innovation consists of steps which research and development efforts take in yielding results such as inventions and discoveries that eventually lead to national competitiveness. A sound investment model will also have feedback loops which contain proposed metrics by which the policy components can be measured in terms of their effectiveness. The metrics include per capita income, jobs created, export volume, company starts, patents, disclosures, trade secrets, prototypes and licensing agreements.This paper reviews and summarizes factors in the economic modeling of governmental investment and associated metrics. Specifically, we describe how the principal factors (namely, human, financial and intellectual capital) of innovation come into play in the formulation, testing, refinement and optimization of science and technology policy of national governments. Factors relevant to S & T policy formulation also include industrial partnerships, degree of overall funding, length of time of policy intercession, global environment, and investment diversity. This overview can be useful to policymakers in formulating or in refining future investments in innovation.

Keywords: Economic policy, National Science and Technology Strategy, Economic Development.

1. INNOVATION, TECHNOLOGY & COMPETITIVE ADVANTAGE

Nations have made investments in scientific and engineering research for several reasons, the most important of which may be the creation of competitive advantage through innovation in one or more of the drivers of the modern world economy. Innovation can be realized in the technology of new material, process or integration of known components that results in an invention or discovery of economic value. Paraphrasing George Heilmeier, former CEO of Bellcore, innovation is technology measured in economic value. Although there may be some disagreement as to today's principal economic driver, some authors (Brownlie, 1992), (Thurow, 1999), (Larson, 2005) believe that technology and its realization in new knowledge or skills constitute the only sustainable advantage that a company or a country could have. Porter (1990) has illustrated a theory of international economic competition in which there are four main inter-acting sectors in a national economy that governmental policy can assist in creating the global competitive advantage – firm rivalry, economic conditions, supporting technologies and infrastructure.

Although private funding of R&D in the US (over $200 B) is far and away much larger in aggregate than that available from governmental agencies, (NSF, 2006) the power of governmental funding is that it can precede and perhaps seed private funding of the areas in which national competitive advantage can be attained. Exemplary results of the focus such governmental funding can bring about in less than twenty five years is the modern manufacturing prowess of China (PRC) and the recognized world class software industry of India. In both of these cases, a specific area of technology was identified for governmental investment and a focused effort was made to support its growth and global competitiveness level. While cost of labor played a role in the launch of the S&T policies in both countries, that factor alone did not create a sustainable advantage. Indeed, the global competitiveness evolved from the skills and knowledge developed by both countries as a combination of training of human capital, financing and innovative applications in establishment, growth, and quality of the technologies of manufacturing and software respectively. The awe that these national achievements inspire is that they were done (a) on a massive scale with thousands of workers requiring training and supervision; (b) in a relative short time frame – about 25 years; (c) in countries with modest amounts of oil and other mineral resources. Indeed, the increase in the economic level of the world's population over the last 25 years is probably due to the GDP advances made by these two countries alone. In Table 1 shown below an illustration is made in the economic advances of both countries in seven years. (CIA FactBook, 2007 & 2000)

Country	Year	GDP/capita (US $)	Agric %	Industry %	Services %
China	1999	3800	15	35	50
	2006	7700	11.9	48.1	40
India	1999	1800	25	30	45
	2006	3800	19.9	19.3	60.7

TABLE 1

One metric that normalizes the population effect is GDP on a per capita basis. For both countries, in just seven years this metric is seen to double in value. The agricultural contribution to GDP in percentage shrinks during the same time period while enhancement is shown in the industry sector for China and the services sector for India.
The power of the governmental investment and support illustrated in the PRC and India examples was enhanced by its focus. The execution of the S&T policy in each country was likely made easier due to the fact that the investment was made in only an extremely select set of technologies – a principal one and its supporting branches or feeders. In the case where insufficient investment is made or the funding is diffused, little progress can be expected. Hence, for each country in relation to the investment level of other countries, a critical mass is necessary to reach a competitive status. (Thurow, 1999).

2. GOVERNMENTAL POLICY IN SCIENCE AND TECHNOLOGY (S&T)

The development of a governmental S&T policy at the national level really depends on the urgency and the substantive goals and objectives of the policy. At a higher level, the governmental entity's S&T policy may aspire to economic development of the region with metrics such as job creation and per capita income. At a mid-level, the policy may have the objective of additional cluster development of existing companies that focus on a specific technology such as laser or similar optical equipment, or medical biometric data storage, or pharmaceutical drug testing. At a still lower level, the policy may have the objective of creating companies that commercialize the storehouse of inventions and discoveries of a large governmental research laboratory or a university that has received federal funding for research or technology that has been licensed from foreign sources.

The government policy in S&T can take on several forms of direct funding, namely, (a) R&D grants, (b) purchasing of products and services that utilize the technology being targeted for value enhancement, (c) infrastructure development such as the construction of a business incubator dedicated to starting companies in a specific S&T field, (d) reimbursement for personnel training in the technologies of interest or offering scholarships in higher education for aspiring technicians and scientist. Indirect funding by the S&T policy can occur through (a) tax incentives to companies that align with the policy's objectives and (b) regulations that encourage rivalry among firms and trade restrictions. These alternatives are depicted in Figure 1.

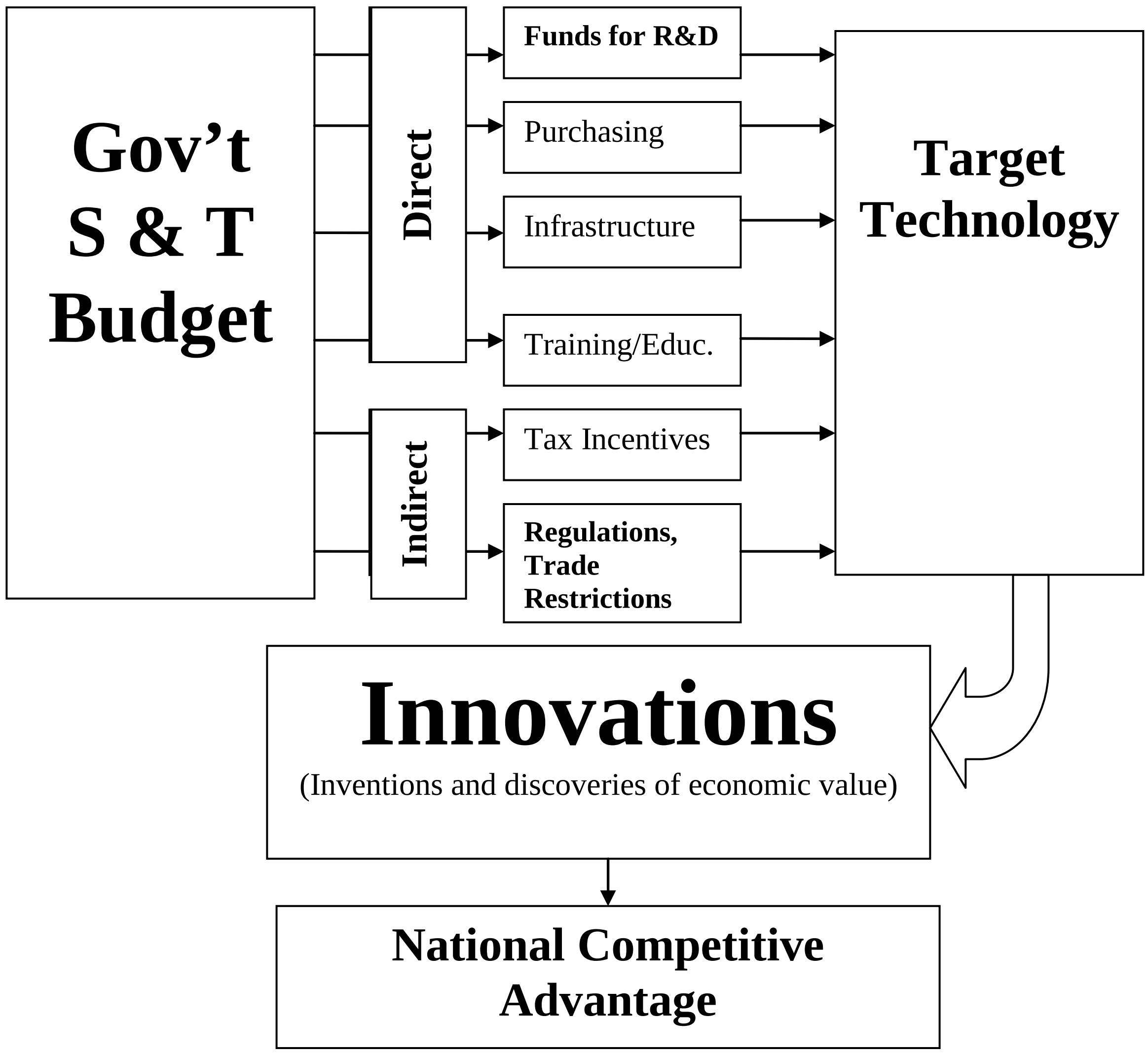

FIGURE 1: GOVERNMENTAL PORTFOLIO INVESTMENT IN TECHNOLOGICAL INNOVATION

3. INNOVATION IN A PRIVATE FIRM

Studies have indicated that innovations in private firms are generated through the interaction of several factors – skills and knowledge in the firm, the firm's environment consisting principally of competition, customers and societal trends, and the information flow between the environment and the firm, consisting mostly of identification and refinement of customer needs and the intake of new skills and knowledge especially of relevant, supporting technologies. (Utterback, 1971) This model is depicted in Figure 2 as an input-output process involving these factors. Although the firm's skills and knowledge are transitory with additions and attrition occurring over time, it is generally conceded that a modest set of these skills and knowledge constitute the firm's "core competencies."(Prahalad, 2000) This model lends itself to measuring the "hard" value created in new products and services by using the financial metric of net income produced by each product. The profitability measure is the ultimate test of market acceptance rather than product sales or product introductions as used in other studies (eg., Hambrick & Macmillan, 1985) The important aspect of this model to note is that, in a private firm, the profit motive is the principal driver for generating innovations. Indeed, this motive is in sharp contrast to that of a national S &T policymaker, namely the creation of jobs, increase in per capita income, higher standard of living – attributes commonly associated with the economic development goal of governmental investment in innovation.

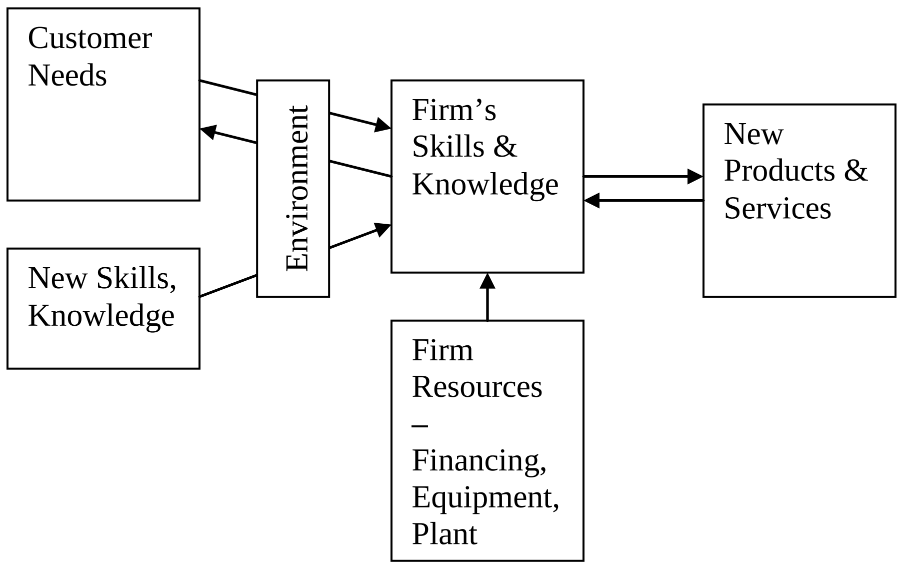

FIGURE 2: INPUT/OUTPUT MODEL OF INNOVATION AT A PRIVATE FIRM

Common among the models proposed for innovation generation in a private firm is the blend of people, ideas and money. The components of people and money constitute capital resources of the firm. Ideas manifest themselves through information flow internal to the company as well as with its external environment. Although the argument can be made that every firm aspires to generating a lucrative innovation, few achieve that goal. Since at least one study (Utterback, 1971) suggests that it is not the firm's capital – human, financing and tangible resources – that are the determining factors in generating innovation, we are left to investigate how the information flow between the firm's environment and the firm can lead to innovation.

Returning to the policy question, in what way can governmental intercession accelerate or encourage and support the innovation process in the private firm? This question is important for USA policymakers since the R&D investment by private firms accounts for over 60% of the USA total.(Larson, 2005) Since the economic value of the technological discovery or invention is what elevates it to the desired level of innovation, what better place for its evaluation than at the private firm? Governmental entities have no means to directly measure the economic value of a discovery or invention. Indeed, it is only the societal impact of the discovery or invention that will ultimately judge its usefulness and economic value. However, governmental assistance towards the commercial success of a technology can occur through the activities listed in Figure 1. For example, an SBIR grant from the USA government is intended to directly fund a small business's development of a technology-based product or service. In addition, Porter (1990) advocates governmental intervention in the form of increased rivalry among firms in order to increase global competitiveness. The latter action is realized through regulations of commerce.

4. DIRECT FUNDING OF INNOVATION BY GOVERNMENTAL ENTITIES

4.1 R&D Grants
In the USA direct funding of research and development of a technology is accomplished through grants and contracts awarded through federal agencies such as the National Science Foundation, National Institute of Health, DARPA and various departments of the Executive Branch of the federal government. Apart from defense related projects which had a budget about $60 billion, such direct funding amounted to about $14 billion in 2003 (Larson, 2005) These awards are frequently made to universities, federally funded national laboratories, non-profit private research laboratories, or for-profit defense contractors in the case of defense or military-related technologies. State, county and city governments also, on occasion, make similar awards usually on a smaller scale and targeted towards an immediate need or application. Since non-federal investments are short-term oriented, the metrics for return on investment such as jobs created, business starts or social returns such as per capita income and poverty rate can be easily used to measure effectiveness of investment. In the USA a modest ($2B in 2004) federal budget is set aside for grants awarded to companies directly such as in the SBIR/STTR category. This compares with the over $60B budget for R&D in USA defense related technologies.
US universities and colleges are the beneficiaries of R&D grants from many federal agencies, this total being flat in the last five years at about $15B. Since the Bayh-Dole Act of 1980, many universities have attempted to commercialize technologies developed from these funds through tech transfer offices.(Colyvas et al, 2002) Except for rare cases, these attempts have led to disappointing results. (Spencer, 2001)(Salazar & Kumar, 2004). A central theme in studies that have attempted to explain the lack of technology transfer from universities is the paucity of industrial and commercial marketing knowledge available to university researchers. (Salazar & Kumar, 2004) This result is also reminiscent of the attempts to establish “technopoles” by governmental agencies in which the industrial and commercial interaction is poor or totally absent. (Cook, 2001)

4.2 Purchasing
Governmental entities account for nearly twenty percent of all purchasing transactions in the US. This tremendous purchasing power can provide significant boost to products and services deploying specific technologies or which are the result of those technologies that governmental entities have chosen to support with direct means. A monumental example of this purchasing power used in the past by the federal government is the direct purchase of foodstuffs such as cheese, processed meat, corn in times of deflated market prices. The purchase preserved the global competitiveness of American farmers until export arrangements could be arranged for food quantities that exceeded the domestic needs. The technologies developed through federal funds for farming and ranching applications since the latter half of the nineteenth century evolved from innovations accomplished through the extension agent-land grant university model. (Rogers, 2005) Today, the US farming output is greater than it was a century ago, all made possible with fewer farms, less land under cultivation and fewer man-labor hours. Innovations in land usage, machinery, seed and crop development, cultivation rotation, pest and weed control all contributed to global pre-eminence of the US in farming techniques. Similar purchasing investments by federal agencies have been made in aerospace such as freight aircraft, avionics, satellites, etc., all contributing to a US global competitive position in aerospace commerce. In fact, as recently as 2006, US-made aerospace products and services accounted for the highest dollar volume of all technology-based exports. (NSF, 2006)

4.3 Infrastructure
Another area in which governmental funds can assist the innovation process is in the improvement of infrastructure that facilitates the commercialization of materials, processes and ideas that result from R&D investments. This commercialization process is critical for establishing the economic value of a discovery or invention. Acceleration of the discovery/invention flow from the laboratory to the marketplace is accomplished by the provisioning and support of business incubators that allow a start-up management team to develop a business concept that exploits the innovation candidate. The importance of a nurturing environment for the an embryonic business has been stressed by several authors (Thurow, 1999)(Kalis, 2001) Indeed, the absence of such an environment has been linked to the lack of business starts.

Infrastructure investments can come in different forms such as in building a deep water seaport and airport as was done in Singapore to enhance its accessibility for trade ventures and contract manufacturing. Similarly, governments can support financial trade markets through infrastructure investments as has been done in Hong Kong, Shanghai, London and New York.

4.4 Education and Training

Of all investments in the process of innovation, arguably the most important is that associated with the development of human capital. Without the creativity and the integrative powers of the human mind, the problem solving process required for innovation would be lacking.

The field of education has been an important investment of S&T policy in both China and India. Each country has reported over 300 thousand engineering graduates in 2005 while the USA had an output of 70 thousand, a number which has declined slightly over the years. Despite the importance of education in the STEM fields for innovation and the emphasis to increase under-represented groups in those fields, since 1995 the proportion of women and minority freshmen in US engineering schools has been decreasing. There has also been a decline in percentage of science and engineering doctorates earned by US citizens, a decrease from 77.5% in 1973 to 58.3% in 2002. (Babco, 2001) In general, some of these problems can be linked to financial problems encountered in public higher education. (Salazar, 2006) A global trend that may greatly impact the USA's competitiveness in innovation is the prodigious increase in the ratio of graduates of science and engineering to 24 year old population by European and Asian countries. Finland, for example, is a world leader with 13% while the US trails with nearly 6%. (Regrets, Chapter 2 in Bell (2004)) Demographic constraints may also cause educated worker scarcity especially in developed countries where a decreasing population trend is underway such as in Japan and many European countries. Except for immigration, the USA would be among those countries as well. The implication is that the future technology worker base may largely reside in developing countries.

5. INDIRECT FUNDING OF INNOVATION BY GOVERNMENTAL ENTITIES

Support for innovation by governmental entities can occur by indirect means such as through tax incentives and regulations.

5.1 Foreign Direct Investment

Nations have imposed restrictions on business investments by foreigners principally to protect domestic companies from predatory competition. These restrictions can take the form of preventing foreigners from owning companies or by imposing excessive import duties on foreign goods, services or components thereof. The expenditure of funds by foreigners in the pursuit of doing business in a country is termed "foreign direct investment" or FDI. In the 1980's China relaxed some restrictions on FDI by permitting foreigners to have ownership in companies located in China and actually created industrial zones in which such companies would enjoy few restrictions in trade into or out of the country. Multinational companies seeking untapped markets and cheaper manufacturing sites and labor supply took advantage of the new policy and thus began a boom era in FDI for China that continues through today. FDI into China was reported as \$100 million in 1990 and \$3.4 billion in 2000. (Story, 2003) India followed suit although its focus has been in services rather than manufacturing. Its software industry grew 40% per year between 1989 and 1995 when it reached \$1.2 billion in revenue. (Naisbitt, 1997)

5.2 Tax Incentives

Governmental agencies use forms of tax incentives such as R&D credits for encouraging and rewarding investments by private firms in engineering. The intent here is the promotion of additional efforts to produce innovations directed to globally competitive products and services. In many cases the R&D credit is given only for covering the expenses incurred in the early stages of research and development and not for the testing, prototyping and initial manufacturing stages. Another type of tax incentive especially by regional authorities is associated with the creation of tax-free industrial zones, the support of R&D through property, plant and equipment financed by issuance of revenue bonds or by a waiver of regional property, asset or income tax. These incentives are intended to encourage companies to use innovation as a sustainable competitive advantage and by so doing also contribute to regional economic development. Such incentives are frequently supplemented with workforce training tax credits as well so that human capital is made available when needed during growth stages of the private firms.

5.3 Regulation and Trade Restrictions

Another point of leverage at the disposal of governmental entities for fostering innovation is the imposition of regulatory controls and trade restrictions intended to protect the unfettered development of technologies during stages of vulnerability from outside competition. For example, US regulations concerning forms of intellectual property such as patents, trademarks, copyrights are frequently used by private firms to protect a discovery or invention during the commercialization process. Rulings clarifying a firm's right to exclusive ownership of technology in US markets are valuable in the innovation process.

Recently environmental and health issues have prompted policymakers to enact legislation that regulates the impact of new technology on society. In some cases, toxicity in the environment has been linked to the unregulated exploitation of technology. The emergence of a new technology or innovation will, under new regulations, require the inventor to describe its impact on society in a circumspect way as was described in (Mesthene, 1969).

6. CONCLUSIONS AND AREAS OF FURTHER RESEARCH

Technology will remain an economic driver in the world economy for the foreseeable future and it presents a challenge to every nation that aims for a more competitive global economic status. The nurturing of innovations is a complex process that involves education, investment and business policies conducive to commercializing an invention or discovery. We have illustrated tactics nations have used to create an innovative business environment for serving the citizenry while growing international markets. There is evidence that points to the sine qua non nature of several of these policies and to the failure of others. Following is a short list of areas or questions that can inspire more research so that some of these tactics can be not only be validated but can be measured as to their impact on a national economic scale.

a. What technology areas should a country invest in?
b. What investments should be made in education and training so as to fulfill the national needs in a technology field?
c. To what degree should direct investments be made compared to indirect investments?

Every country will have to formulate an S&T policy best for its investment in innovation. Those who have enjoyed wealth from mineral extraction, agriculture or a strategic location are vulnerable to technological advances that diminish the value of their assets. Today, a national economic strategy must take on the challenge that innovation brings, both on an offensive and defensive front.

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Author Profile:
Dr. Andres C. Salazar earned his PhD at Michigan State University in 1967. Currently he is Professor and Chair of the Computer and Engineering Technology Department at Northern New Mexico College, Espanola.