

**Techno-Economic Paradigm Shift and  
Contemporary Justification of STI Policy in  
Korea and the United States**

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## I. INTRODUCTION

During the past few decades, the dramatic changes have been globally witnessed in the ways of technological advances and economic developments. These global changes have been so dramatic and fundamental that they are often regarded as a paradigm shift, which encompasses deep structural changes rather than incremental changes in both the size and scope of their impact on economic activity (Gera and Hirshhorn 2000). More or less, such a paradigm shift is represented by the transition from the traditional 'brick-and-mortar' economy to a 'knowledge-based economy' (KBE), in which the knowledge, rather than the capital or labor, becomes the more critical factor for the sustaining economic growth.

Many observers do not hesitate to argue that the emergence of the KBE is closely linked to the intensifying globalization and the rapid technological advances in some infrastructural areas such as information and communication technology (ICT), biotechnology (BT), advanced materials, etc. These factors have profoundly changed the ways to innovate and produce the industrial products and services. The mass-production under the traditional economy has changed to the digitalized production networks. Increasing internationalization of production greatly helped by the numerous multinational enterprises no longer validates the rationale of domestic competition policies to a greater extent.

Such a techno-economic paradigm shift from the traditional economy to the KBE has also challenged the science, technology, and innovation (STI) policies and national innovation systems (NIS). Policymakers face distinct challenges in overcoming the obstacles impeding their economy's progress as a KBE. In a shifted techno-economic paradigm, significant adjustments in STI policies and NIS are also requested.

Although the observed techno-economic paradigm shift is global, the requested adjustments in STI policies and NIS may vary between the leading countries like the US and the catching-up countries like Korea. Requested is an in-depth investigation on the

rationales for government STI policies in both groups of countries – the leading and catching-up countries. It may offer a learning experience for each other either in leading or catching-up group of countries. The efforts of the leading economies to develop mechanisms that strengthen science/industry links for example should be instructive for the catching-up countries such as Korea, and vice versa.

Focusing on Korea and the US as the cases each representing the leading and catching-up countries in different stages of economic and technological development, this study purports to identify the appropriate justification for government STI policies under a new/emerging techno-economic paradigm, i.e., the so-called knowledge-based economy (KBE). For this main purpose, through extensive literature review, we try to:

- identify the characteristics of the new/emerging techno-economic paradigm,
- review the different policy rationales for science, technology, and innovation,
- examine the STI policies in Korea and the US, and
- induce the appropriate STI policies and their rationales.

The research consists of six chapters including this introductory chapter. In chapter 2, we will identify the prominent characteristics of currently on-going global techno-economic paradigm shift. Chapter 3 reviews the two different policy rationales for science, technology, and innovation. Chapter 4 examines the STI policies of the US and reviews the underlying rationales for them. By the same token, Chapter 5 analyzes the STI policies of Korea and reviews the underlying rationales for them. Finally, Chapter 6 draws out the policy implications for the two countries based on a comparative analysis of the Korean and the US cases.

## II. TECHNO-ECONOMIC PARADIGM SHIFT

Since Kuhn (1962) first used the term ‘paradigm,’ it has been widely utilized in various fields to denote the more profound and structural changes rather than the simple ones. Given that the currently on-going changes in technological advances and economic development are more profound and structural than ever, they are more than often regarded as the ‘techno-economic paradigm shift’ rather than simple changes or progresses. The new techno-economic environment being emerged from this paradigm shift is most often referred as a ‘knowledge-based economy’ (KBE). It is because the knowledge increasingly becomes the most important factor for technological advances and economic development in a new environment. Instead of KBE, some literatures use other terms such as ‘new economy,’ ‘information economy,’ or ‘digital economy’. These terms, however, often refer only to a subset of the whole economy by focusing on specific characteristics (McKeon and Weir 2000). For this reason, the ‘knowledge-based economy’ is used in this study as a comprehensive one that denotes a new techno-economic environment emerging from currently undergoing paradigm shift.

What are the specific changes in the currently on-going techno-economic paradigm shift, then? And, what are the major driving forces for this shift? Among others, many literatures seem to agree that rapid advances in some infrastructural technologies and intensifying globalization are the two most critical driving forces for the current techno-economic paradigm shift. Being driven by these forces, profound changes have been occurred in structures of industrial governance, which have consequently resulted in the emergence of KBE. More importantly, these changes have subsequently led to some dramatic changes in the government policies for innovation. Altogether, these changes constitute the current paradigm shift. In this chapter, we critically discuss such profound and structural changes and their implications.

## **1. Technological Advances**

Rapid advances in some ‘infrastructural’ technological areas such as information and communication technology, biotechnology, and advanced materials penetrate into the whole economy. In more recent years, nanotechnology has been added to this list. These technological areas are ‘infrastructural’ in the sense that they have widespread use outside the originating sector (Vonortas 1997). In other words, infrastructural nature implies that the underlying technologies in each of these areas affect a wide array of industries ranging from agriculture to mining to manufacture and services. During the past decade, the information and communication technology has been the most ‘infrastructural’ among them, but the others have followed in close range.

Not only are these technological areas ‘infrastructural,’ they also have very ‘fluid’ nature (Vonortas 1997). Fluidity means that these technological areas have no well-defined technological trajectories, save for narrow product ranges. This is most visible in information and communication technology (ICT), which can be defined as hardware and software with the capacity to identify, retrieve, store, process, and communicate words, numbers and images and to control and connect equipment and processes. For these characteristics, these technological areas are hard to define.

Among others, the information and communication technology (ICT) has been the most significant foundation of the new and currently undergoing techno-economic paradigm shift. ICT however is not a single technological area but a broad cluster, to which technological advances in three major technical areas including computer hardware and software technology, communication technology, and networking technology have contributed. Each of these technological areas had independently evolved in the past for a considerable period, but has gradually converged during the past few decades to produce the so-called ‘digital revolution.’

As these technologies interactively advance and converge, previously distinct boundaries between telecommunications, computing and mass media have become increasingly blurred. This converge has propelled the industrialized world into an age of high-capacity

network computing, multimedia communications, and ‘information superhighways.’ In a digital world, the networks used to transmit voice, data, and video can be unified in the same transmission systems and be connected to computing equipment. As a result, an ever expanding range of technologies and products fall under the term “information and communication technology” including:

“... telephones, facsimile machines, computers, switches, compact discs, video and audio tape, coaxial cable, wire, satellites, optical fiber transmission lines, microwave networks, televisions, scanners, cameras, and printers as well as advances in computing, information, and networking not yet envisioned. ... [Beyond hardware and software, information technology] is also a system of applications, activities, and relationships. There is the information itself, whatever its purpose or form, e.g., video programming, scientific or business databases, images, sound recordings, library activities, or other media. There are also standards, interfaces, and transmission codes that facilitate interoperability between networks and ensure the privacy and security of the information carried over them, as well as the security and reliability of the networks themselves.” (Department of Commerce, 1995).

The area of biotechnology has also been undergoing equally important redefinition of its technological trajectories with the newly acquired capabilities for DNA/RNA sequencing and gene manipulation. These capabilities rely heavily on technological trends not only in the biological sciences and technology but also in micro-electro-mechanical systems, materials, imaging, sensor, and information technology (Anton, Silberglitt et al. 2001). ‘Bio-infomatics’ for example is an emerging area resulted from blending biotechnology with information technology.

An OECD (OECD 2000) study points out two prominent characteristics of biotechnology. One is that it grounds in science very closely. So the boundary between fundamental discovery and application has become so hard to define. Another is biotechnology’s increasing pervasiveness. It has the ability to penetrate a growing number of human activities: agriculture and food, industry (all sectors using or treating organic materials),

energy production, healthcare and pharmaceuticals, environmental protection through bioremediation and pollution control, and even law enforcement (e.g., forensic science). These characteristics represent exactly the ‘infrastructural’ and ‘fluid’ natures of biotechnology.

With the newly acquired capabilities for creating novel materials atom by atom to fit the exact specifications, the advanced materials technology is also in the process of defining its technological trajectories. Its core element lies in that it pursues to produce products, components, and systems that are smaller, smarter, multi-functional, environmentally compatible, more survivable, and customizable. These products will not only contribute to the growing revolutions of information and biology but will have widespread additional effects on manufacturing, logistics, and personal lifestyles (Anton, Silbergliitt et al. 2001). Hardware advances for exponentially smaller, faster, and cheaper semiconductors will fuel information technology, which in turn increase the availability of low-cost computing and enable the development of ubiquitous embedded sensors and computational systems in consumer products, appliances, and environments. Nanomaterials such as semiconductor “quantum dots” could begin to revolutionize chemical labeling and enable rapid processing for drug discovery, blood assays, genotyping and other biological applications (Anton, Silbergliitt et al. 2001). The necessary capabilities have heavily been supplied by the recent advances in nanotechnology.

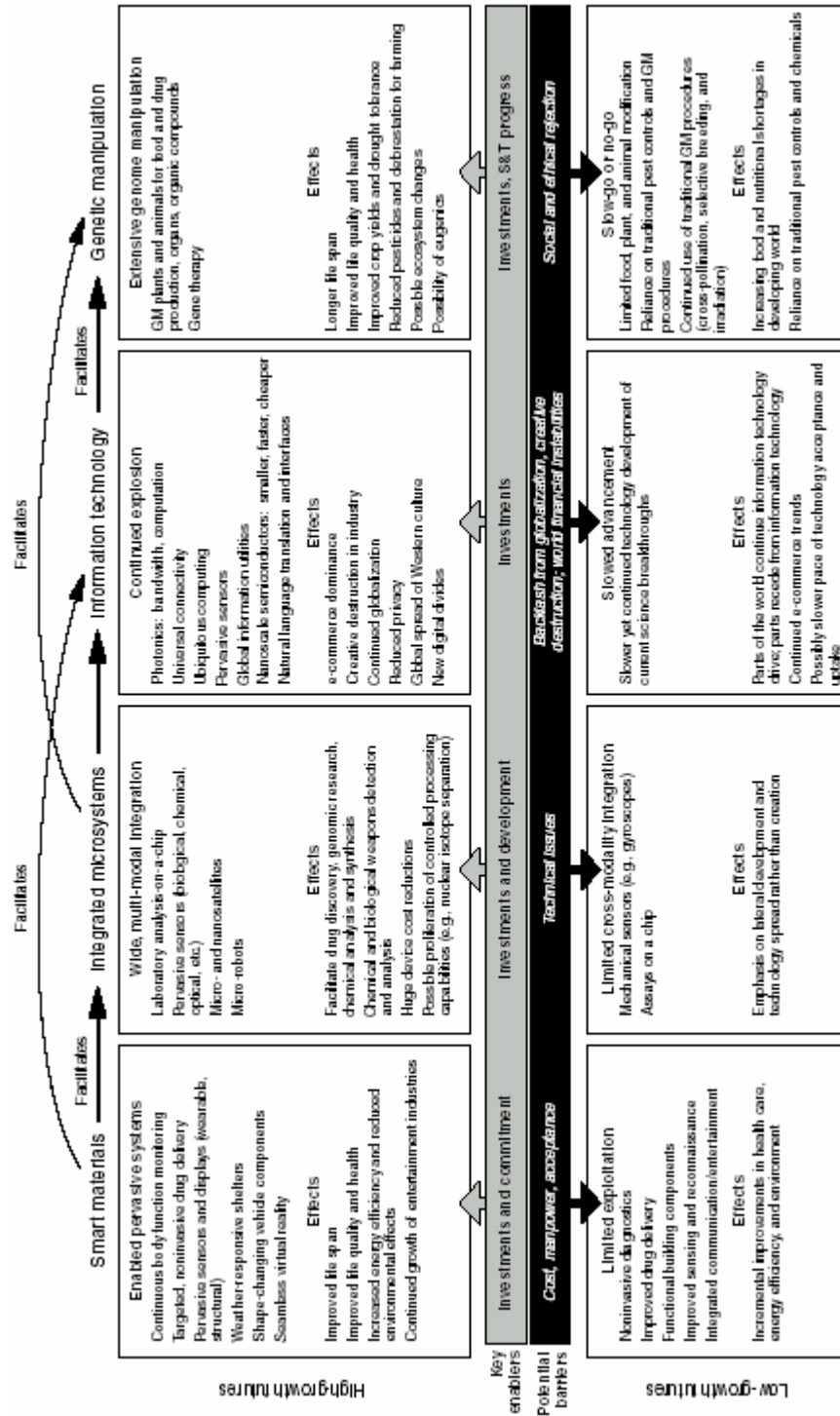
Differently from the other technological areas mentioned above, nanotechnology is not a connected group of disciplines but a loosely defined methodology, which focuses on manipulation of materials at nano meter ( $10^{-9}$  m) scale and can be exploited in a wide range of disciplines. The essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization (IWGN 2000). Structures and components of materials and systems exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes at their nanoscale size. Nanotechnology aims to exploit these properties by gaining control of structures and devices at atomic, molecular, and supramolecular levels and to learn to efficiently manufacture and use these devices.

It was not however until the 1980s, when the instruments such as scanning tunneling microscopes, atomic force microscopes, and near-field microscopes were invented, that nanotechnology was visible. Another development was expansion of computational capability, which enabled sophisticated simulations of material behavior at the nanoscale. These instruments and techniques provide the “eyes” and “fingers” required for nanostructure measurement and manipulation to the scientists and engineers from many disciplines.

The impacts of nanotechnology are pervasive. As pointed out earlier, nanotechnology has provided significant foundation to the advances of new materials technology. A report for the National Nanotechnology Initiative (IWGN 2000) well illustrates some potential benefits that are expected from the systemic efforts on nanotechnology. It for example is fundamentally changing the way materials and devices will be produced in the future. Its benefits are not confined to advanced materials and manufacturing but expanded to a wide range of technological areas including nanoelectronics and computer technology, medicine and health, aeronautics and space exploration, environment and energy, biotechnology and agriculture, national security, science and education, global trade and competitiveness, and other government applications (e.g., DOT, EPA, DOJ, BEP, etc.).

One important observation is that these technological areas are rapidly advancing by interacting with each other to a considerable extent. They are not isolated to each other but heavily depended on the advances in other technological areas for their further advances. Indeed, they evolve interactively. During the past few decades, the astonishing advances in ICT have provided robust foundations for the emergence of biotechnology, nanotechnology, and advanced materials technologies. With the help of ICT, nanotechnology has in turn stimulated the developments of ICT and biotechnology to a significant extent. Convergences among these areas have often created new technological fields such as bio-infomatics, micro-electro-mechanicals system, biomimetics, etc. The following table is an example illustrating the interactions of these technological areas and their potential effects (Anton, Silberglitt et al. 2001).

Table 1. Interactions of Key Technological Areas and Their Effects



Source: (Anton, Silbergliett et al. 2001), Table S.1, p. xix

A comprehensive foresight study of RAND (Anton, Silbergliitt et al. 2001) points out the meta-trends and implications of these key technological areas as follows:

“Taken together, the revolution of information, biology, materials, devices, and manufacturing will create wide-ranging trends, concerns, and tensions across the globe by 2015.

- ***Accelerating pace of technological change.*** The accelerating pace of technological change combined with “creative destruction”<sup>2</sup> of industries will increase the importance of continued education and training. Distance learning and other alternative mechanisms will help, but such change will make it difficult for societies reluctant to change. Cultural adaptation, economic necessity, social demands, and resource availabilities will affect the scope and pace of technological adoption in each industry and society over the next 15 years. The pace and scope of such change could in turn have profound effects on the economy, society, and politics of most countries. The degree to which science and technology can accomplish such change and achieve its benefits will very much continue to depend on the will of those who create, promote, and implement it.
- ***Increasingly multidisciplinary nature of technology.*** Many of these technology trends are enabled by multidisciplinary contributions and interactions. Biotechnology will rely heavily on laboratory equipment providing lab-on-a-chip analysis as well as progress in bioinformatics. Microelectromechanical systems (MEMS) and smart and novel materials will enable small, ubiquitous sensors. Also, engineers are increasingly turning to biologists to understand how living organisms solve problems in dealing with a natural environment; such “biomimetic” endeavors combine the best solutions from nature with artificially engineered components to develop systems that are better than existing organisms.
- ***Competition for technology development leadership.*** Leadership and participation in development in each technical area will depend on a number of factors, including future regional economic arrangements (e.g.,

the European Union), international intellectual property rights and protections, the character of future multi-national corporations, and the role and amount of public- and private-sector research and development (R&D) investments. Currently, there are moves toward competition among regional (as opposed to national) economic alliances, increased support for a global intellectual property protection regime, more globalization, and a division of responsibilities for R&D funding (e.g., public-sector research funding with private-sector development funding).

- ***Continued globalization.*** Information technology, combined with its influence on other technologies (e.g., agile manufacturing), should continue to drive globalization.
- ***Latent lateral penetration.*** Older, established technologies will trickle into new markets and applications through 2015, often providing the means for the developing world to reap the benefits of technology (albeit after those countries that invest heavily in infrastructure and acquisition early on). Such penetration may involve innovation to make existing technology appropriate to new conditions and needs rather than the development of fundamentally new technology.”

The most important observation however would be the penetration of these technological areas into other technological areas, whole industries ranging from manufacturing to agriculture and to services, and eventually whole economy. The penetration of these ‘infrastructural’ and ‘fluid’ technologies throughout the economy has dramatically altered the basic meaning of high technology during the past few decades. Rather than referring to the output of R&D-intensive industries, high-tech now refers to a style of work applicable to just about any business (Branscomb and Florida, 1998). One can have high tech steel production and low tech steel production: high tech machine tools and low tech machine tools; high tech entertainment services and low tech entertainment services; and so forth. Certain business analysts have gone on to claim that we no longer have high and low tech industries but only high and low tech firms (Porter, 1998).

## **2. Globalization**

Globalization has swept the whole world economy since mid 1980s in various forms. However, it is generally conceived that globalization denotes two core changes prevailed throughout the world during the past few decades.

First, it denotes the increasingly integrating world economy largely due to the worldwide liberalization and deregulation of economic policy. As the international trade barriers including tariffs and other intangibles have been reduced significantly, international trade and investment have tremendously increased, international capital market has been liberalized more than ever, and many multinational enterprises (MNEs) have grown and played much more important roles in the international trade. These changes have led to increases of international flows of investment, goods and services, people, and ideas and eventually resulted in increased integration of most advanced economies into the world economy.

Second, globalization also denotes the intensifying competition and increasing cooperation among countries. As the world economy has been increasingly integrated, on the one hand, it has increasingly intensified competition among countries more than ever, it has also increasingly created opportunities of new forms of cooperation among countries and/or economic agents, on the other hand. In turn, diffusion of new ideas, knowledge, and technologies has been further encouraged through these intensified competition and cooperation.

It might be useful here to distinguish ‘globalization’ from ‘internationalization,’ of which concept is similar to that of the former and, because of this, often confusingly used for the former. Although the terms are still fuzzy and ill-defined, it is generally accepted that ‘internationalization’ is a phenomenon of the 1950s-1960s and a large part of the 1970s while ‘globalization’ refers to the changes that took place during the 1980s and since after (OECD 1996). The latter is a new and more complex stage in the process of the former. The internationalization of the economy has gradually entered a phase of globalization during the 1980s.

An OECD (OECD 1996) study points out two major changes that have led this transition; i) deregulation policies and ii) information and communications technologies. Firstly, the deregulation policies primarily applied to the financial section, competition policy, and other service sectors (e.g., air transportation, telecommunications, etc.) have significantly liberalized international trade during the 1980s by freeing capital movement, easing competition laws, and eventually allowing horizontal mergers to the greater extents. Deregulation and liberalization in international trade have extended further spurred by several major developments in international relations in 1990s.

The first development was the birth of European Union (EU) in 1993, which was formally established by the so-called the 'Maastricht Treaty' of 1991 in order to promote economic integration and expand cooperation among European member countries. As soon as the EU launched, another big free-trade zone, North American Free Trade Agreement (NAFTA), was formed in North America in 1994. NAFTA has greatly encouraged the free trade, elimination of tariffs, protection of intellectual property rights, and discussion on labor and environmental issues among three northern American countries, US, Canada, and Mexico.

The effort for free trade has been extended not only in regional but also in global level. In 1995, World Trade Organization (WTO) was newly organized to replace the General Agreement on Tariffs and Trade (GATT). By accepting all 128 nations that were contracting parties to the new GATT at the end of 1994 and additional 16 nations by the 2002, WTO became the largest international organization that promotes and enforces the provisions of trade laws and regulations for the free trade.

Secondly, to the greater extents, globalization has been driven by rapid advances in information and communication technologies (ICT) and transportation technologies. Automobiles have ever increased backed up by increasing traffic roads. Ships have been getting bigger. Airplanes have been ever safer and faster. More importantly, the wide-scale dissemination of new communications technologies has liberalized and accelerated international transactions (cross-border movements of information and capital, data transmission, etc.). Computers in the network have encouraged more frequent

communication. Emails, web pages, mobile phone, fax, and satellite have been frequently in use and dramatically increased in numbers.

Rapid advances in these critical technologies have permitted direct and ongoing access and made possible automated worldwide management of the banking and financial system, transport, commercial transactions and personal communications (OECD 1996). The acceleration of the flow of information has allowed firms to adopt more decentralized and more autonomous modes of organization, on the one hand, has made possible greater centralization of certain strategic services, on the other hand. The rapid advances of ICT and transportation as well have in fact made possible and easier for the most advanced economies to increase their interactions with other countries by significantly reducing the transaction costs.

The immediate consequence of deregulation and the advances in communication technology was an unprecedented strengthening of world competition and the emergence of “global competitiveness”. By this is meant the need for firms to be able to mobilize a range of skills simultaneously.

The major changes resulting from globalization are profound. OECD (OECD 1996) summarizes the main resulting features of globalization as follows:

- ***Simultaneous competition*** in each market between numerous new competitors from all countries. Each firm now has to compete in its own market with other firms and new players from all over the world. This new competition necessitates in numerous areas extremely rapid structural adjustment.
- ***Internationalization of production***: multinational origin of components, products, services and capital. The various elements that enter into the manufacture of a product (capital, labor, technology, raw materials, intermediate goods, distribution) may come from many sources; countries and firms are now so interdependent, and the links between the so complex, that it is sometimes quite difficult to determine exactly where the various elements come from.
- ***Growing interdependence*** of the various levels of globalization (trade, direct

investment flows, technology transfers, capital movements, etc.). High degree of interpenetration of national economies.

- The structure of international trade is becoming increasingly *intra-industry or intra-product in nature*.
- *Diminished importance of trade*, which is no longer virtually the sole vector of globalization.
- *Foreign direct investment* has become a crucial factor in the worldwide process of industrial structuring and the development of genuinely global industries. Direct investment flow generates exports from the countries making the investment; these exports are accompanied by transfers of technology and know-how, and capital movements (equity investments, international loans, repatriated profits, interest, royalties, etc.).
- “*Absolute advantages*” are once again a factor in trade.
- *National comparative advantages* increasingly correspond to advantages of location, which vary according to corporate strategies.
- *Financial sector* tightly entwined with the industrial sector.
- *Emergence of specific regional and cultural factors* in response to globalization. Multiplication of regional free trade agreements.

As a part of the process of globalization of the world economy, the science and technology activities have been also internationalized. Even though research and development activities are less internationalized than those relating to production, they have nonetheless grown significantly over the past few decades. Another OECD (OECD 1998) report points out that the internationalization of science and technology activities are realized in two forms: i) the growing internationalization of R&D activities as a result of an increase in the number of R&D laboratories located abroad and ii) the rising number of cooperation agreements or alliances either between firms or between firms and government or university R&D bodies. While the first of these trends is restricted to multinational firms, the second is typical of all categories of firms.

Besides these forms of internationalization of S&T activities, NSF (NSF 1998) also recognized a number of other features as follows:

- Many countries are investing in science and technology as a key economic strategy
- S&E education is increasing globally
- The S&T workforce is becoming more global
- Scientific publications are increasingly international in character
- Industrial firms are developing international alliances
- Foreign patenting activity demonstrates the global nature of technology
- Trends in royalties and fees indicate global flows of technological know-how
- Foreign direct investments in R&D are increasing and demonstrate S&T globalization
- International trade in technology products is another indicator of S&T globalization

### **3. Industry Governance Structures**

The impacts interactively produced by rapid advances of key technological areas and intensifying globalization have been dramatic during the past few decades. First of all, the industrial governance structures have fundamentally changed by the forces of technological advances and globalization. The fundamental changes in industrial governance structures can be summarized as the transformation from the traditional 'brick-and-mortar' economy to a 'knowledge-based economy (KBE),' in which knowledge becomes more important driving force for growth rather than traditional economic components (e.g., labor, capital, etc.). Although the main features of KBE will be comprehensively discussed in the next section, a number of them are closely related to the changes in industrial governance structures.

As globalization intensifies and technological advances in some key areas (especially, in information and communication technologies) progress, one of the most prominent changes might be the unprecedented strengthening of global competition (OECD 1996). As most national markets have ceased to be protected markets for domestic firms, firms are no longer confined in domestic markets but driven to compete in global markets. Each firm now has to compete in its own market with other firms and new players from all over the world. The various elements that enter into the manufacture of a product such as capital, labor, technology, raw materials, intermediate goods, distribution may come from many sources all around the world. Competitiveness in global markets consequently requires firms to be able to mobilize simultaneously a broad range of specialized industrial, financial, technological, commercial, administrative and cultural skills located in different regions and to combine them synergistically.

One of the immediate consequences of intensifying global competition is the emergence of a new type of corporate organization that may be called 'global' or commonly called 'Multinational Enterprises' (MNEs). These MNEs have tried to compete everywhere in the world by introducing the same products or services using same production techniques and same works organization in increasingly alike world markets. The technological advances in ICT have made such global operation of MNEs possible to a great extent.

Confronting with the national differences (such as those in wage rates, inflation rates, exchange rates, interest rates and, more generally, in levels of industrial and technological development, institutional rules, language, cultures, etc.), they have been able to exploit national differences (advantages of location) while at the same time minimizing them (via the firm's internal market).

At the same time as the global competition has intensified and the role of MNEs in global market has increased, new forms of cooperation or business networks have also significantly increased at various levels. To focus on their core activities, firms have tried to outsource non-core activities. For these complementary activities or assets, they have instead depended much on medium-term cooperative agreements or alliances with other specialized firms. Research and development is often considered as the excellent area for such cooperative agreements or alliances. Traditionally, R&D activities were under the tight control of centralized units. To strengthen their technological capability, firms have two options: a) internalize activities via mergers or acquisitions of other innovative firms, or b) adopt an external approach to cooperate with other firms around a common program through agreements or alliances. As cooperation in R&D has significantly increased, in-house R&D centers of major firms have opened up to other firms to a certain extent, which has in turn led to the growth of knowledge flow between them. In most cases, nonetheless, the cooperation has focused on generic or pre-competitive areas and has been reserved to members within the network.

Internal networks have also been strengthened extensively. Firms have tried to rapidly adjust to localized markets (demands) and changing environments by adopting very decentralized operational structures. This decentralized structure has in turn raised the need of integration, which has led to the growth of 'firm networks' to a significant extent. The technological advance of ICT, spread of robotics and flexible manufacturing systems, and economies of scope replacing economies of scale have also been conducive to the growth of 'firm networks' by improving the ability of firms to integrate the local partners as well as to adjust to local demands rapidly. Indeed, the strategies of competitive firms are "to externalize some of their activities in sectors that have attained a certain degree of maturity and simultaneously enter into technological alliances to develop new products or processes." (OECD 1996)

The same OECD (OECD 1996) report summarized the global strategies that competitive firms have adopted in these changed industrial governance structures as follows:

- Global conception of markets
- Refocusing on core activities
- Priority given to external expansion
- Striving for critical mass
- Rapid increase in agreements and alliances
- Firm networks
- Changes in internal organization (e.g., the transition from Fordism to Toyotism)

In addition to, but closely related to, the aforementioned changes, some other shifts in industrial governance structures have been observed. These shifts are mainly related to the innovative capabilities of competitive firms. First, manufacturing firms are changing their corporate archetype from 'producing organization' to 'thinking organization' by dramatically increasing their corporate R&D investment. The traditional archetype of a manufacturing company is a group of people who produce high-quality products at the lowest possible cost, using the most advanced equipment. The contemporary trend however indicates that high-tech companies spend more on research and development (R&D), primarily focusing on long-term researches for their future business, than equipment investment (capital investment).

Second, the contemporary innovations come more often from fusion of different types of technology rather than a technical breakthrough in a discipline. While the conventional wisdom holds that technical innovation is achieved by breaking through the boundaries of existing technology, the contemporary innovations are mostly the results of blending various related technologies, as could be seen in ICT, biotechnology, advanced materials, and nanotechnology. To a great extent, the rapid increase of cooperative R&D among related industries has been conducive to the growth of such technology fusion. Moreover, innovation through technology fusion results in more complex processes of innovation so that the simple linear innovation model is no longer valid.

Kodama (Kodama 1988) summarizes these observations as six ‘paradigm shifts’ in S&T as follows:

- Manufacturing companies from producing organization to thinking organization
- Business from single technology base to technology diversification
- Innovation patterns from technical breakthrough to technology fusion
- R&D activities from visible competitors to invisible enemies
- Technology utilization from single-purpose technology to dual-use technology
- Innovation process from linear progression to non-linear process

In a changed techno-economic environment, the importance of service sector industries has also grown to an extensive degree. The technological advances in key areas (especially, of information and communication technologies, ICTs) have been conducive to the growth of services sector industries to a significant extent due to their infrastructural properties. They have deeply penetrated into the wide range of industries including both manufacturing and service sectors. The penetration of these infrastructural technologies has gradually shifted the locus of high technology production from exclusively manufacturing to a combination of manufacturing and service industries (Vonortas and Tolnay 2000).

Revolutionary advances of ICTs have been rapidly transforming the nature of the products of both sectors by penetrating into a wide range of industries. On the one hand, manufacturing has become more like services: customer service has become more important and products have been increasingly being tailored to the needs of individual customers. It is estimated that service activities such as design, sales, and advertising have already contributed to over three quarters of the value of a typical manufactured product (OECD 2000).

On the other hand, penetration of ICTs is changing the production and consumption patterns of the product of some of the most valuable and fastest growing service sectors

(e.g. business services including software development) by making it easier to break the link of a one-to-one relationship between supplier and customer. Consequently, direct contact between producer and consumer has become unnecessary as information technologies make it easier to codify knowledge in some services and allow such services to be held as inventories and be traded internationally (e.g., expert computer systems).

Traditionally, the role of service sectors, which already account for almost three-quarters of advanced economy GDP, has been appreciated as only consumers of high technology products. Its inadequacy however has been recently exposed as more service sectors are seen to directly participate in the R&D efforts either independently of or in association with manufacturing sectors. The convergence of high-tech manufacturing and several service sectors is indeed another phenomenon in a new techno-economic paradigm.

#### **4. Knowledge-Based Economy**

It is widely agreed that the newly emerging techno-economic environment resulting from the forces and changes described in previous sections may be called as a 'Knowledge-Based Economy' (KBE). Although it is still not widely agreed on the definition of KBE, the essence of KBE lies in that KBE distinguishes itself from the old/existing economy in that knowledge becomes one of the most critical factors for creating wealth throughout the economy.

This essence is well noted in an OECD (OECD 1998) study, in which KBE is defined as "A knowledge-driven economy is one in which the generation and exploitation of knowledge play the predominant part in the creation of wealth." This definition is in line with that of McKeon and Weir (McKeon and Weir 2000) who rightfully describe the KBE as the "one in which the production, distribution, and use of knowledge is the main driver of growth, wealth creation and employment across all industries." Such definitions indeed reflect an increasing recognition of the role of knowledge in economic growth. More than that, they imply that a KBE encompasses the exploitation and use of knowledge in all production and service activities; not just those in the so-called 'high-tech' or 'knowledge-intensive.'

Embodied in humans and in technology, 'knowledge' has always been central to economic development. In KBE, however, the role of knowledge has taken on greater importance than other traditional factors such as natural resources, physical capital, and low-skilled labor. The advanced economies are more dependent than previously on the production, distribution and use of knowledge, which can be evidenced by the faster expansion of output and employment in high-tech industry segments in both manufacturing such as computers, electronics, and aerospace and services such as software, banking and finance, and telecommunications (Vonortas and Tolnay 2000). This increasing role played by knowledge in the economy and society as whole, which has been mutually reinforced by the rapid development and pervasive use of a whole range of ICTs, could have been observed from various aspects (Foray and Lundvall 1996).

First, an increasing amount of resources has been devoted to the production, the transmission and the use of knowledge, as the importance of investment in R&D, education, and labor training in sustaining and raising living standards has been rising. According to Kendrick (Kendrick 1994), the investment in education and training, health, safety and mobility and in R&D has been dominant since the mid-70s and its ratio on tangible capital has doubled between 1920 and 1990.

Second, the importance of knowledge-intensive sectors is growing to a significant extent. At the promise of faster expansion of output in the knowledge-intensive sectors or high-tech industries, investments into high-tech goods and services have been increasing more than ever. Information and telecommunication technologies (both hardware and software) have been at the investment forefront. Even though there are controversies on the definition of knowledge-intensive sectors, it is clear that their share in the GNP has strongly increased, especially recently. An OECD (OECD 2000) study, based on its elaborate definition of knowledge-based industries, shows that since the mid 90s, the share of these sectors in business added value has reached the 50% level in the EU and in the US, and its rate of growth from 1986 to 1996 has been higher than the average rate of growth of the business sector.

Third, the share of high-skilled workers is also increasing. As the chasm between skilled and lesser or unskilled labor tends to widening, skilled labor has been in high demand across most advanced countries whereas unskilled labor is being discarded (unemployment rates range from about 4% for workers with university degrees to about 11% for workers without in OECD countries). Particularly strong has been the growth for non-production, knowledge-based jobs. For instance, the average annual increase of knowledge-workers (scientists, engineers, ICT specialists, etc) amounted to 3.3 % during from 1992 to 1999 in the US and EU countries, which is much higher than 2 - 3% for the previous ten years (OECD 2001). For both periods, this rate was significantly higher than the one of any other groups of occupations (especially the low-skill based group).

Fourth, knowledge and innovation have had an increasing importance in the competition processes. Partial evidences of this tendency may include the diversification of products,

the number of new products put on the markets, the number of new firms based on new products or completely new domains, the apparently endless reduction of time to markets, the reduction of products and technology life cycle, etc.

McKeon and Weir (McKeon and Weir 2000) identify these general features as the four key dimensions of a KBE:

- ***Innovation system***: Innovation and technological change are pervasive and supported by an effective national innovation system (i.e., a network of institutions in the public and private sector whose activities and interactions initiate, import, modify, and diffuse new technologies and practices).
- ***Human resource development***: Human resource development is pervasive: education and training are of high standard, widespread and continue throughout a person’s working life (and even beyond).
- ***ICT infrastructure***: An efficient infrastructure operates, particularly in information and communications technology (ICT), which allows citizens and businesses to readily and affordably access pertinent information from around the world.
- ***Business environment***: The business environment is supportive of enterprise and innovation. (The term “business environment” includes the economic and legal policies of government, and also the mix of enterprises operating in the economy.)

In each dimension, they (McKeon and Weir 2000) propose more specific desirable characteristics that an idealized KBE should have. They are presented in Table 2.

Table 2. Characteristics of a Fully Developed KBE

CHARACTERISTICS	IN KBE
<b>Innovation System</b>	
Promotion of Innovation	Supportive culture within firms, society and government
Capacity to assimilate knowledge from	Strong, helped by skill base and internal

outside	creativity
Relationships between firms and research institutions	Close relations between firms with complementary skills and between firms and research institutes, assisted by formal and informal mechanisms
Technology diffusion	Actively facilitated
Role of small and medium enterprises (SMEs)	Numerous new technology based firms
Role of Knowledge Management	Knowledge actively acquired and well shared within firms
<b>Human resource development</b>	
Investment in intellectual assets	Including human capital, widespread
Education and training system	Near universal base education to at least upper secondary
Policies that encourage lifelong learning	In industry, government and education institutions
Preservation of intellectual capital	Good knowledge/information management systems
Other knowledge	Also needed and valued, e.g., management, cultural
Knowledge workers	Employment dominated by knowledge/information work
<b>ICT Infrastructure</b>	
Telecommunications	Advanced telecommunications widespread and affordable
Role of ICT	ICT important as enabling technology
Government and other investment infrastructure for ICT	Necessary as support to KBE
<b>Business environment</b>	
International orientation	
- Growth in (foreign investment) FDI	Indicates confidence in economy
- Growth in trade	Strong performance and global orientation
- Knowledge networks	Strong international links of knowledge

- Openness	Ready entry of new ideas and products
- Immigration	Skilled migrants embody new ideas
Knowledge-based industries	Knowledge intensity high in all industries
Role of Government	As market facilitator, rather than dominant participant
<b>Regulatory environment for business</b>	
- Financial system	Transparent, efficient and open
- Capital formation	Available venture capital
- Intellectual property rights	Protected but open knowledge
- Competition policy	Encourages innovation
- Sound macroeconomic foundations	Conducive to prosperity
- Transparency in corporate governance	Avoidance of cronyism
Social Values	Reflected in policy
Information needed for democracy	Readily available and used

Source: McKeon and Weir (McKeon and Weir 2000), Table 1. Summary of Characteristics examined with Indication of Their State in a Fully Developed KBE, pp. 136-137.

Despite such features for the emergence and development of KBE, it has not been clear yet around what kind of knowledge is exactly becoming increasingly valuable in KBE and how it is created and diffused. To answer these questions, there have been some attempts to classify various types of knowledge. One is to distinguish between four kinds of knowledge: ‘know-what,’ ‘know-why,’ ‘know-how,’ and ‘know-who’ (Lundvall and Johnson 1994). ‘Know-what’ is knowledge about facts. This kind of knowledge is closer to the normal meaning of information. ‘Know-why’ is scientific knowledge about the natural world, society, and the human mind. This kind of knowledge is codifiable in the form of notes, publications, databases, etc., which are typically developed in organizations such as universities and research laboratories. ‘Know-how’ refers to skills and the ability to do things on a practical level, which are typically developed within individual firms. ‘Know-who’ refers to the understanding of who knows what and who knows how to do what. This kind of knowledge is closer to what is usually meant by the term tacit knowledge (ITAG and Ernst & Young 1999).

Another is to distinguish the two types of knowledge: a) ‘codified knowledge’ that is formally recorded in writing or otherwise, and b) ‘tacit knowledge’ that is only in someone’s head (Foray and Lundvall 1996; McKeon and Weir 2000 ). These two kinds of knowledge differ greatly in terms of the ability one has to transfer and communicate them effectively and cheaply.

On the one hand, information and codified knowledge is quite mobile across large geographical distances. Impressive advances of ICTs have greatly facilitated the effective handling of know-what and know-why kinds of knowledge. ICTs have given a strong impetus to the process of knowledge codification by increasing the value of the resulting information that comes about from the ability to transmit them at low cost across great distances. It is codification that makes it possible to characterize contemporary economies as information societies. Foray and Lundvall (Foray and Lundvall 1996) point out the importance of codification as follows: it (codification)

- reduces the costs of and accelerates knowledge acquisition and dissemination,
- turns knowledge into a commodity (information), thus facilitating market transactions,
- facilitates knowledge externalization and allows firms to increase the amounts of knowledge they can acquire at a given cost, and
- helps directly speeding up knowledge creation and innovation.

On the other hand, know-how and tacit knowledge is not immediately transferable. Such knowledge primarily remains specific to organizations and locations. Lundvall and Borrás (Lundvall and Borrás 1999) argue that:

“...knowledge remains tacit if it is complex or variable in quality: in situations where several different human senses need to be used at the same time, when skilled physical behavior is involved and when understanding social relationships is crucial. This is especially difficult to overcome when the context undergoes rapid change.”

Consequently, tacit knowledge is very much the result of experience rather than formal education and training.

In KBE, nonetheless, tacit knowledge is generally considered to be equally important to codified and explicit knowledge. It is because as the available stock of information increases and access to it becomes easier and less expensive, a new set of skills and competencies (in large part tacit knowledge) that enable the efficient selection and use of it become ever more important. The ability to codify information faster, which has been much facilitated by remarkable advances of ICTs, has extensively contributed to accelerating the stocks of accessible knowledge. At the same time, it has also accelerated the obsolescence rate of produced knowledge, which has in turn incurred the serious adjustment costs for labor and economy. An important kind of cost is that involved in acquiring a range of skills (tacit knowledge) in order to be able to effectively make use of an increased amount of information. Apparent is the importance of tacit knowledge.

Learning is required for the accumulation of such tacit knowledge. That is, the ability to learn both codified information and the competencies to use this information effectively and efficiently become core prerequisites of a KBE. Implication is clear: a balanced investment in development of codified and tacit knowledge is necessary for the efficient operation of a KBE (OECD 1996). Lundvall and Borrás (Lundvall and Borrás 1999, p.33) point out the interdependence of codified and tacit knowledge in a KBE as follows:

“Therefore, there are two important limits to the codification process. First, the fact that codified and tacit knowledge are complementary and coexisting means that there are natural limits to codified knowledge. ... And second, increased codification does not necessarily reduce the relative importance of tacit knowledge - mostly skills and capabilities - in the process of learning and knowledge accumulation. Actually, easier and less expensive access to information makes skills and capabilities relating to the selection and efficient use of information even more crucial than before.”

In that the importance of learning capacity of agents is clearly recognized and

emphasized, the term ‘learning economy’ is closely related to the concept of KBE. It is used to emphasize the learning and cognitive dimension of phenomena that drive the economy.

“Simply defined, a learning economy is an economy where the ability to learn is crucial for the economic success of individuals, firms, regions, and national economies. ‘Learning’ refers to building new competencies and establishing new skills and not just to ‘getting access to information’.” (Lundvall 1997)

The so-called ‘new economy’ however seems not an appropriate term for describing the features of KBE, although this term is most frequently used to qualify the recent evolution of the most advanced modern economies. It is because it tends to take too narrow views by focusing primarily on the importance of ICT-based sectors and on the role of purely technical innovation and neglecting other profound tendencies related to the production, use, and diffusion of knowledge.

All the preceding discussions on the concept of knowledge clearly show that the key asset of KBE is the learning capacity of agents, firms, and any other organization. This learning capacity allows them to create, share, diffuse, and use new knowledge, whether tacit or codified, and whatever its form of codification. In addition, it makes them to be able to change, to adapt to new economic and social conditions, and most of all to create better conditions. In this perspective, it becomes the most important policy element to put a huge effort for supporting any form of education, for adults as well as for children, in order to avoid polarization between learning and non-learning sub-sets of our modern societies, which would inevitably results in inequalities in social as well as economic terms.

## **5. Policy Shift**

Each country is forced to align its existing policies as well to cope with the profound and structural changes including rapid advances in some infrastructural technological areas, intensifying globalization, and industrial governance structures (and thus to go forward to a fully developed KBE). In the manners of interacting and mutually reinforcing, these driving forces and structural changes have led the advanced economies to the so-called 'Knowledge-based Economy.' Beyond that, they have also produced challenges and stimulated the national policies to effectively adjust to these new and emerging techno-economic environments. Paradigm shift is also going on national policies for innovation.

The policy implications implied by the currently on-going techno-economic paradigm shifts are profound. One is that a remaining thought government policies should favor manufacturing sectors because it creates 'real' wealth and 'proper' jobs should be discredited. To a larger extent, such a misleading notion has made governments to inappropriately pay attention to only a part of the supply-side of the market for high-technology manufacturing sectors.

Another comes from, together with discredit of the aforementioned misleading notion, the discussions on KBE (and more directly on the concept of valuable knowledge in KBE). It is that distributed knowledge, skill, and entrepreneurship, along with new forms of collaboration between firms, universities and government, can result in more effective products and services. Consequently, the very policy instruments that should be used for promoting economic growth under the new emerging techno-economic environment are to be profoundly different from those under the older techno-economic environment. It is now widely recognized that science and technology policy should move away from policies granting preferential treatment to certain well defined manufacturing sectors. Instead the less direct policy instruments simultaneously seeking the ways to maintain and enhancing a nation's knowledge infrastructure should be adopted.

These implications become obvious from the fact that the learning ability is the key asset of a 'Knowledge-based Economy.' Lundvall and Borras (Lundvall and Borras 1999)

argue that the revolution in ICTs and the globalization, which is partly resulted from the breakdown of institutional barriers to change internationally (deregulation and market liberalization), have worked to speed up the changes, on the one hand, and to raise the value of tacit skills needed to make use of increasingly cheap codified knowledge effectively, on the other hand. These two outcomes (a faster rate of change and a rising value of tacit skills needed for effective use of codified knowledge) together in turn make the learning ability important more than ever. Accordingly, the favored in KBE are those individuals, firms and nations with the ability to learn effectively and efficiently.

This ‘learning ability’ approach to the KBE has important implications not only for firm strategy but policy as well. On the firm strategy front, it is necessary for firms to learn to link changes in their intellectual capital (or intangible assets in more traditional economic term, which include both the stock of knowledge and the ability to enhance it) to the worth of their business and balance sheets (ITAG and Ernst & Young 1999). Indeed the multinational enterprises have been conceptualized dominantly based on the ability of their organizational structures to exploit their superior intangible assets.

However, this is not a new requirement since a firm’s intellectual capital has always been a source of competitive advantage. What is new is that the value of intangible component far outweighs the value of their tangible assets for an increasing number of firms in high-technology manufacturing and service sectors. As Kodama (Kodama 1988; Kodama 1995) observed in more than a decade ago, many firms in manufacturing sector are turning into ‘thinking organizations’ that are spending more on building their intangible assets through research and development (R&D) than on building their tangible assets through investment in traditional capital. Not only this process has been intensified in manufacturing sectors but exploded in knowledge-intensive service sectors as well.

In the meanwhile, the importance of learning ability in a KBE has cast a much more important implication to the policy front. It is a call for a more comprehensive policy scheme. Lundvall and Borrás (Lundvall and Borrás 1999) have drawn attention to three sets of policy:

- Policies that affect the pressure for change (competition policy, trade policy, and

- general economic policy);
- Policies that affect the ability to absorb change (human resource policy, innovation policy);
- Policies that assist the losers from change (social and regional policies with central objective to redistribute wealth).

While the first set of policies provide impetus for the knowledge-based economy by enabling or limiting the functioning of KBE, the third set of policies make the profound changes associated with the KBE to be accepted and tolerated by society. Given this, it becomes a too narrow approach to limit its attention only to the second set of policies above, which has been a dominant trend in appraising the knowledge-based economy to date. Accordingly, requested is a comprehensive analysis of the interaction of all three policy dimensions.

It is obvious that in the future the best performing economies will be those whose governments help develop and manage their knowledge assets most effectively for innovation. From this perspective, technology policy thus needs to revert to innovation policy, which is much more technology-user centered and demand-based than the technology policy has been until now. At the same time, innovation policy must also be better integrated with other policies including:

- general economic policies that affect incentives to innovate,
- policies that shape the regulatory and institutional environment in which innovation takes place, and
- policies that provide appropriate safety nets for the parts of the population that fail to follow the ever increasing pace of change.

### **III. Rationales for STI Policy**

This chapter analyzes the economic rationales of the science, technology, and innovation (STI) policies argued in various theoretical literatures, which provides more robust theoretical foundation for the discussions done in the previous chapter. The analysis is carried out by: a) identifying the main theoretical economic frameworks on the basis of on what economic terms the innovation related phenomena are currently analyzed, and b) deriving, from each framework, the justifications for government intervention as well as the main forms that this intervention may take. It is important however to emphasize that we have not artificially separated the science from technology policy. It is because each framework provides rationales for science policy, technology policy, or more broadly innovation policy (and even for others, e.g. competition policy, trade policy, education policy and so on) and, more importantly, all these policies are based on the same rationale in each framework.

We distinguish between two main economic frameworks: mainstream and evolutionary structuralist. For each framework, we have identified:

- main features, especially regarding innovation,
- circumstances and consequences of the so-called ‘failure,’
- principles of government intervention to remedy these failures, and
- main problems raised by these principles.

## **1. The Mainstream Economic Framework**

Although it has been strongly challenged by the other one, this framework has been the most coherent and dominant one of the two frameworks. These are why it is named as the ‘mainstream economic framework,’ rather than the ‘neo-classical economic framework,’ which is another title commonly used to denote one school of thoughts in this framework.

In this mainstream economic framework, the innovative activity is mainly viewed as the one performed by individual agent (innovator including firm) using input (investment) to produce a particular good or output (technological knowledge), which is largely considered as information. Firms are prevailing performers of innovative activities, which are mostly called as ‘research and development’ (R&D). The core of this framework however lies in the argument that ‘market failure’ inevitably occurs due to the so-called ‘lack of incentives’ in the market of innovative activities.

Market failure generally denotes the economic situation in which the social rate of return is greater than the private rate of return (Jang 2000). Firms perform innovative activities as the name of industrial R&D to generate technological knowledge, whether for producing new products or for reducing production costs of the existing goods. However, they will invest in industrial R&D only to the extent that they can privately exploit the benefits of their R&D results. If the social benefits from private investment on industrial R&D are much larger than the private benefits, the privately optimal level of investment is much lower than the socially optimal level of investment on industrial R&D. From the standpoint of social surplus, there is ‘under-investment’ in industrial R&D. From the standpoint of private innovator (firms), there is ‘lack of incentives’ to invest in industrial R&D to the social optimal level. Eventually, there exists a ‘market failure’ in industrial R&D.

The sources of ‘under-investment’ or ‘lack of incentives’ in industrial R&D are various but all are closely related to the characteristics of outcomes (technological knowledge) and processes of industrial R&D activities. First of all, the lack of incentives are derived

from strong characteristics of technological knowledge as a 'public good.' The two salient characteristics of public goods are 'non-rivalry' and 'non-exclusivity' in consumption (Gramlich 1990). Public goods are 'non-rival' since the consumption by one party does not diminish the quantity of another party's consumption. They are 'non-exclusive' because it is very costly to exclude others from consuming the public goods. Technological knowledge has such 'public goods' characteristics that inevitably lead to a 'free-rider' problem in the market system. At the expectation that they will benefit others who avoid paying their fair share of costs in producing technological knowledge, no one would invest at the socially optimal level in industrial R&D.

Second, there exist 'externalities' in innovative activities. Technological knowledge is generally understood to create the so-called 'positive externalities.' The positive external effects are those benefits from market transaction that accrue to third parties but are not paid for. They are not thus incorporated into the market demand or supply (Gramlich 1990). In the case of industrial technology, positive externalities are usually referred to as 'research spillovers' in three different forms (Vonortas 1997):

- '*pecuniary or market spillovers*' the occur when the producer of a new or improved product/process is not able to appropriate all additional returns to buyers or consumers;
- '*knowledge spillovers*' that occur when the technological knowledge is transferred without adequate compensation; and
- '*network spillovers*' that occur when the successful implementation and economic value of a new technology is strongly dependent on other complementary technologies.

By adversely affecting the incentives of individual firms to invest in industrial R&D for innovation, these research spillovers also frequently create severe 'free-rider' problems that lead to market failure.

Third, individual firms are often confronted with the 'uncertainties' in producing technological knowledge with a broader scope of discipline. Due to economies of scope embedded in industrial R&D, it becomes more difficult and uncertain for firms: a) to

successfully produce the required technologies, and b) to fully appropriate the resulting returns. The former is ‘technological uncertainty’ while the latter is ‘market uncertainty.’ These uncertainties also lead to market failure by lacking incentives for individual firms, particularly small and non-diversified firms, to invest in industrial R&D.

Fourth, the industrial R&D markets also fail very often because of the high transaction costs incurred by problems of ‘impactedness’ and ‘opportunism’ (Vonortas 1997). ‘Impactedness’ refers to the difference in incentives between the seller and buyer of a piece of technology. Sellers hesitate to disclose all the information relating to that technology before the completion of transaction because that disclosure might diminish the value of the technology. Buyers also hesitate to complete the transaction before the disclosure because the value of that technology is uncertain. In such a situation, ‘opportunism’ arises and creates severe *ex ante* disincentives for individual firms to invest in industrial R&D, which ultimately lead to market failure.

To a significant extent, all the above characteristics of technological knowledge create disincentives for firms to invest in industrial R&D and lead to an inefficient allocation of S&T resources, i.e., market failure. Confronted to these market failures, the mainstream economic framework has paved the road to government intervention in the market of industrial R&D. That is, public actions take over private actions that would be required to reach the socially optimal level of investment by remedying such market failures due to public goods characteristics, externalities, uncertainties, and/or transaction cost. The line of the argument in this framework is following: since the ‘first-best’ equilibrium could not be reached because of these market failures, a ‘second-best’ equilibrium can be reached by allowing government intervention to correct these market failures, at least. Although the ‘second-best’ equilibrium is inferior to the ‘first-best’ one, it is better than if there had not been any government intervention.

The basic policy principles generally asserted to remedy these market failures in this mainstream economic framework are following: government should

- provide a better information in order to reduce the uncertainties related to innovative activities,

- substitute wholly or partially for the market to the extent reaching the social optimum, and
- promote mechanisms or regulations to remove or diminish the externalities.

A number of policies have been justified based on these basic principles provided by the mainstream economic framework. They have mainly aimed to reduce or share the uncertainty, risk, and/or cost related to innovative activities. On the supply side, government may carry out itself innovative activities or help firms to invest in R&D by means of subsidy, grant, tax credits, etc. while, on the demand side, government may also help firms through procurement of products and services resulted from industrial R&D. In order to remove or diminish the externalities, government may either provide proper level of protection on intellectual property rights or promote cooperation in industrial R&D including vertical cooperation between users and producers of technology (market externalities) and horizontal cooperation between producers of technology (knowledge externalities).

Critics focused on what is called ‘government failure’ or ‘policy failure’ have been immediately raised. It is argued that government intervention in the market of industrial R&D may also fail. Government fails because solving a given market failure makes another market failure. The crucial question is the balance between the positive effects resulting from the correction of the first and the negative effects of the second. If corrective government intervention creates other market failures worst than the ones that were supposed to be solved (i.e., the increase in social surplus obtained thanks to the government intervention is inferior to the decrease in social surplus induced by the induced market failure), it is the situation where ‘government failure’ replaces ‘market failure.’

Two primary sources of government failures can be pointed out. First, it is argued that government intervention entails ‘moral hazard.’ If public monies were available to underwrite all or parts of expenses for industrial R&D, then individual firms would have the incentive to take as much public funding as they could get. In this condition, even the small expected private returns would become very attractive to individual firms and technological knowledge would be inefficiently overproduced (Ouchi 1989).

Furthermore, such moral hazard expands to encompass the questions of ‘who should be the beneficiaries of public funding on industrial R&D’ and ‘whether public monies may be used for private wealth.’

Second, government fails because of ‘bureaucracy.’ Examples may include the inflexible decision making processes within large bureaucracies, increasing possibility of mistakes, untimely technology assessment, or research pork barrel. All these examples are the unsolvable chronic problems occurred in the processes of public decision-making, where private interests always flow in through lobbying and etc. Furthermore, it is not guaranteed that government has more information and better capacity to acquire new information than the market. In this situation, transferring industrial R&D under the aegis of the government would most likely be a simple replacement of ‘market failure’ with ‘government failure.’

Problems also arise from the specific policies proposed to correct market failure as well. They are closely related to the intellectual property rights (IPR) system. By giving the exclusive (monopolistic) control over the produced technological knowledge to the producers, it is supposed to correct the market failures originated from the characteristics of ‘public good’ of the outcomes of industrial R&D. By such legal rights, the outcomes of industrial R&D becomes partially exclusive ‘quasi-public goods’ not the perfect ‘public goods.’ Monopolistic power over the produced technological knowledge would obviously strengthen the *ex ante* private incentives for industrial R&D.

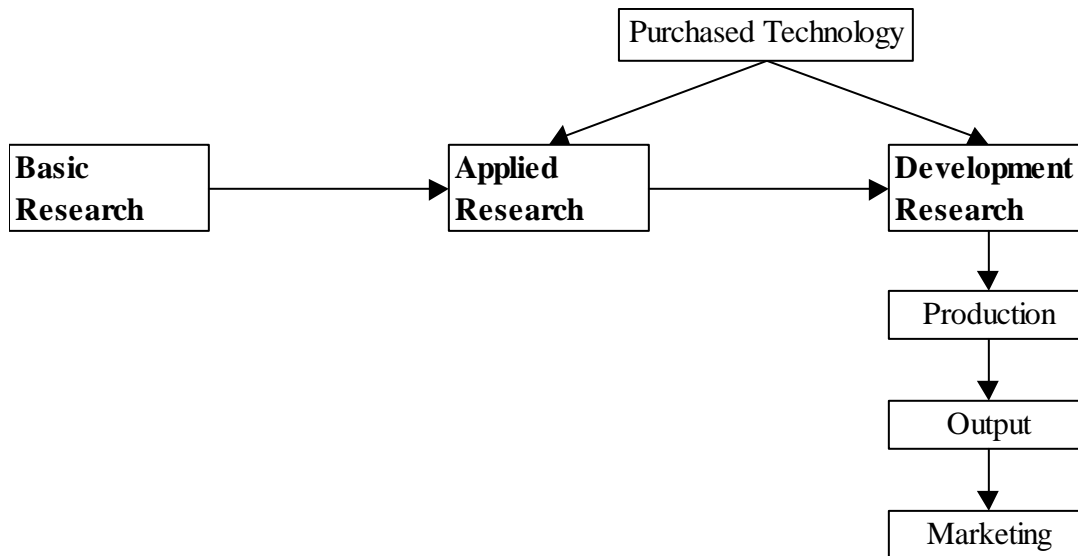
Nonetheless, intellectual property rights system (IPR) has several intrinsic problems. First, once produced, technological knowledge under monopolistic control would be used too little from the standpoint of social surplus since the technological knowledge is still non-rival – i.e., one’s consumption still does not diminish the quantity of other’s consumption (Rosenberg 1990). Second, IPR system does not prove to be an effective solution for the aforementioned ‘positive externalities’ because of its difficulty to specify the exact property rights. Third, it may induce duplication innovative efforts by firms in competition for being the first to be protected. This may lead to over-investment when a number of firms are racing for patents, or conversely under-investment when a firm dominates the ‘patent race.’ Both results would not be socially optimal. Fourth, it

introduces asymmetries of information between actors by giving the exclusive rights over the introduced information to the inventors. Given the 'pure neo-classical' axioms that the social optimum can be reached only if all agents have the same information, the reachable equilibrium under IPR system is only a 'second-best' one, at best. This last point is very relevant to the subsidy, which causes asymmetry to the one who benefits or not, and to the promotion of cooperation, which restricts the diffusion of information and economic gains to a limited number of agents.

The other problem is closely related to the identification of the situation in which 'market failures' occur, and most of all the identification of 'where' to correct them. In the mainstream economic framework, it is often argued that not all kinds of technological knowledge have the aforementioned 'public goods' characteristics to the same extent and that the most severe market failure is expected on generic knowledge, often referred to as 'pre-competitive' in the sense that it can be applied to a broad spectrum of specific technologies to be competitively developed.

According to Nelson (Nelson 1989; Nelson 1990), generic knowledge is 'a body of generic understanding that surrounds a set of specific practices and provides interpretations of why they work as they do.' This kind of knowledge is different from scientific knowledge in that it significantly depends on previous experiences with particular products and processes and has a functional focus, and also from specific practices (technologies) in that it has a broad spectrum of possible applications and can be fairly easily disseminated to experienced experts in the same fields with relatively small learning costs. Generic knowledge is generally considered as a very 'leaky' property because it is weakly appropriable by the inventor and, thus fully belongs neither to private firms having weak incentives for investment nor to public institutions using tax monies (Ouchi and Bolton 1988). Consequently, the private incentives of generic research activities are severely discouraged, resulting in under-investment in and under-production of particularly the generic knowledge (Williamson 1991). The most severe market failure occurs in generic research.

Figure 1. The Linear Model of Innovation

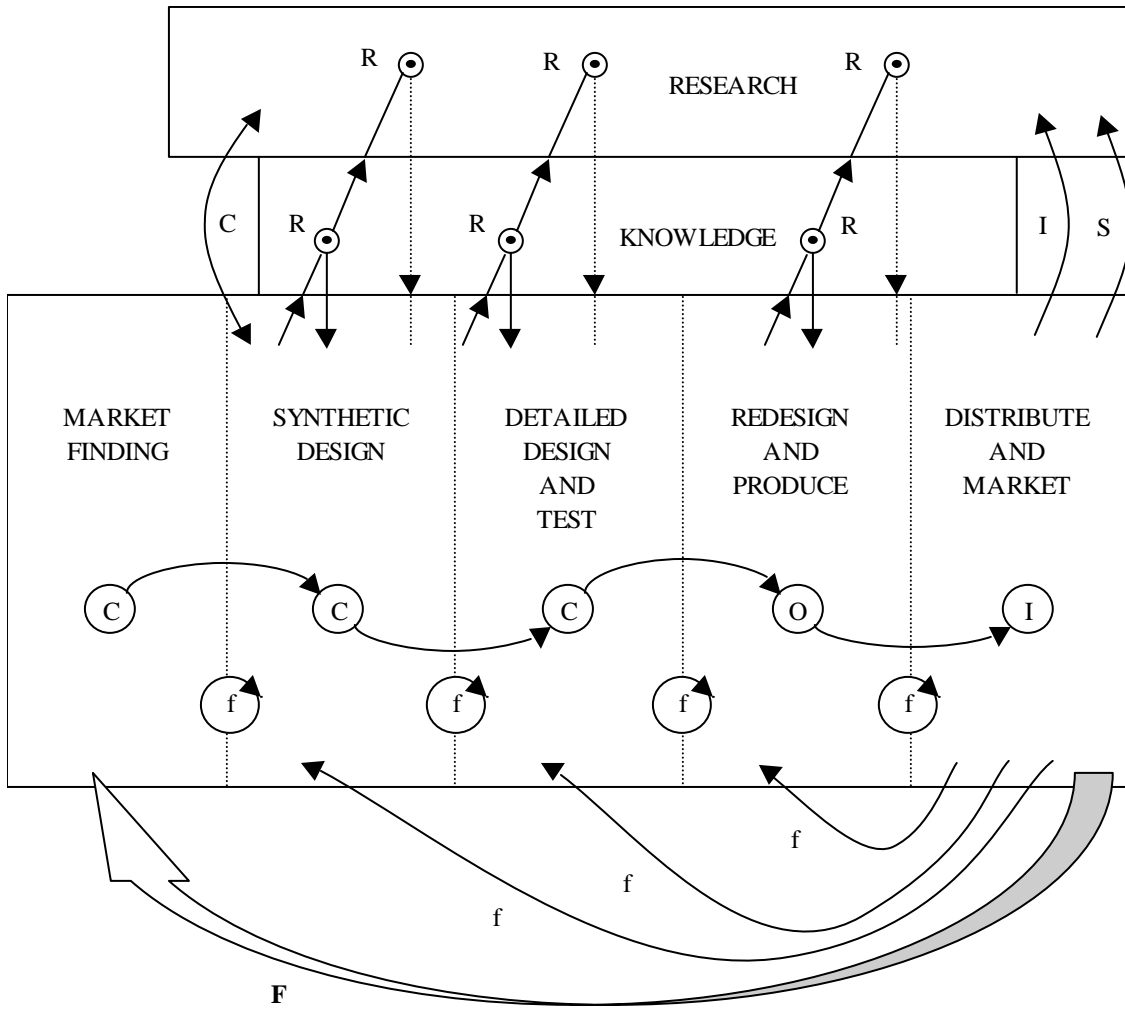


Source: Adapted from Vonortas (Vonortas 1997).

The major drawback of this conventional view is however that it is based on an oversimplified assumption of ‘linear’ (sequential) technological advance as depicted in Figure 1. This model postulates that innovation proceeds an unidirectional path from basic research to applied and development researches followed by production, distribution, and marketing. There are no feedback loops or interactions among the sequential steps. Each stage of innovation is clearly identifiable in this simple and logical model (Jang 2000).

In reality, however, the notions postulated by the simple ‘linear’ model of innovation have become obsolete or unrealistic. As observed in the previous chapter, the techno-economic environment of the past few decades, especially after the 1980s, is vastly different from those assumed by the simple ‘linear’ model. Rather, as depicted in Figure 2, the changed innovation pattern is that new ideas for innovation can occur at any stage, of which boundaries are increasingly becoming blurry, and they flow back and forth among various activities. These blurred activities may even be considered as a compressed parallel process by the simultaneous model of innovation (Teece 1989).

Figure 2. The Chain-Linked Model of Innovation



Symbols used on arrows:

C-C-C-O-I (path): Central chain of innovation for products

C: Origination of problems and creative ideas generated in research

f: Feedback loops for information flow

F: Particularly important feedback, especially for new models of products

K: Access of stored knowledge

R: Links to and from research projects

S: Sustaining company support for long range research in areas relevant to current or intended product lines

Source: Adapted from Kline and Rosenberg (Kline and Rosenberg 1986).

## 2. The Evolutionary Structuralist Framework

The evolutionary structuralist framework consists of a constellation of approaches that have some strong common features. Among them, the most prominent approaches may include the following three:

- *'Evolutionary theory'* mainly focused on evolution of technologies, firms, industries, etc. that is guided by diversity/selection process,
- *'Systemic/Network approach'* mainly focused on coordination, complementary, and various institutions in national and/or regional systems of innovation, and
- *'Knowledge-based economics'* mainly focused on knowledge processing.

Although each of these main approaches has focused on some different specific aspects and respectively provided the 'general logic' of the evolution, the 'how it works,' and the 'basic engine' of evolution, the concepts and analytical tools developed by each approach have been complementarily used as indispensable bricks for conceptual construction of the whole framework by being adopted by the other approaches. Thus they more or less explicitly share the same features to a considerable extent. With the emergence of knowledge-based economies, they have rapidly developed, refined, and gained its coherent grounds. They have been mostly inspired by other disciplines such as sociology, psychology, management, epistemology, and so on rather than economics. But, most of all, by claiming part of the heritage of Schumpeterian views, they have commonly built against the mainstream economic framework reviewed in the prior section.

It is obvious from this background that most of the main features of the evolutionary structuralist framework are to a considerable extent opposite to the ones of the other framework, the mainstream economic framework. The first and probably the most prominent feature of this framework is that the learning or more generally the cognitive capacity of all agents or groups of agents is fully acknowledged in this evolutionary structuralist framework. Learning capacity here embraces a capacity to change the ways of thinking, beliefs, visions, routines, etc. in order to learn existing knowledge as well as to create new knowledge. The cognitive capacity for innovation is thus closely relevant

to a balanced mix of codified and tacit knowledge as well as the scientific and technical knowledge, which cannot be reduced to pieces of information. In the evolutionary structuralist framework, innovative activity therefore becomes a cumulative and collective learning process rather than a purely individual process. This learning process is so dependent on context that it varies from one agent, group of agent, firm, industry, clusters of industry, region, institutions, etc. to the other.

Second, in this learning-oriented framework, there is neither a static nor a dynamic equilibrium-like situation as is in the mainstream economic framework. Correspondingly, there is also no optimality to reach or achieve. Instead, there is only a 'good trajectory' to follow or a 'good transition' to ensure. By reinterpreting and enriching the Schumpeterian cycle analysis, the main approaches in this evolutionary structuralist framework have reached to an apparent consensus. It is the recognition of system as the one, in which all phenomena and processes are so complex and intrinsically related that the equilibrium, whether the first- or second-best, becomes almost meaningless. According to such recognition, a system follows some trajectories induced by paradigm. What is really important is therefore to make sure for the system to be able to exploit a 'good trajectory' as well as ensure a 'good transition' from one paradigm to the other. In order to be able to do so, there should be enough diversity and well performing selection processes in the whole system and at all levels of the system. The basic engine allowing all of this is to increase and maintain the cognitive capacity of all agents or groups of agents at all levels of the system.

Third, closely related to the second point, what is basically matters in this framework is the problems that limit the cognitive capacity of agents or groups of agents in the system and refrain its use, which are generally referred to as 'learning failures.' They are largely resulted from the 'traps,' 'dysfunctions,' 'gaps,' or 'holes' that lead to 'dilemma' and 'trade-offs' between existing forces driving the system rather than those between the possible states of the system (e.g., (Metcalf and Georghiou 1998) (Lundvall 1997). There are four types of 'learning failures':

- *exploration/exploitation failures*: misallocation of efforts or cognitive attentions to one activity to the other;

- ***selection failures***: technologies, practices, firms, etc. are wrongly under-represented or over-represented in the process of selection;
- ***system failures***: lack of coordination and complementarity between cognitive activities of agents, rigid cooperative structures, lack of appropriate institutions allowing a collective creation and diffusion of knowledge, and bad adjustment or desynchronization between the institutional evolution and technological evolution;
- ***knowledge processing failures***: codification problems due to the lack of standards and platforms, inappropriability of codes, or excess of standardization, limited absorptive and emitting capacity, lack of capability to articulate knowledge coming from different sources, or structure of knowledge badly adapted to appropriate sharing and distribution.

A number of negative consequences are resulted from these different types of learning failures. Largely, they are the lock-ins in ‘bad trajectories.’ They include: a) the lack of diversity in the system, b) the difficulty of making new paradigms emerge or warrant the transition between old and new paradigms, and c) the existence of ‘gaps’ in terms of knowledge, networks, institutions, economic and social conditions, etc., which make the evolution of the system unbalanced.

The basic principles of government policy proposed in this evolutionary structuralist framework are to: a) help the agents, institutions, industries, regions, and all others to develop and reorient their cognitive capacity, and b) provide the conditions of use of this capacity, by all possible means. These principles of public policy for innovation are essentially based on the following recognition, which can be easily drawn from the main features of the evolutionary structuralist framework: the use of the cognitive capacity is supposed to provide the conditions for appropriate selection processes, sufficient diversity among which the selection mechanisms operate, without too many ‘gaps’ in the system, which in turn would guarantee the evolution of the system along satisfying trajectories and through relevant paradigms.

Different approaches developed in this framework have put the different emphases on different aspects. Correspondingly, very different policy actions have been proposed by

different approaches. However, they all have commonly aimed to prevent or cure the negative consequences resulted from all such types of ‘learning failures.’ More importantly, they all underline the context-dependent policies. That is, the proposed policies should not be universal but should be adapted to contexts defined in terms of regions, industries, sections, markets, institutions, or any other dimensions. Policy actions generally proposed in this framework include:

- reinforce the role of institutions, infrastructures and collective interactions,
- help to the codification process
- support the development of knowledge infrastructure allowing for a better use of the increasing amount of codified knowledge within the whole society.
- promote norms, platforms or other knowledge-related infrastructures,
- support communities and agents of knowledge,
- reinforce and adapt the education system,
- renew the intellectual property right system to take into account not only the cumulative nature of knowledge creation but also the nature of the knowledge and of its other modes of appropriation,
- support infant firms (SMEs) at their different stages of development

As it may be already implied from the above discussion, the boundaries among science policy, technology policy, and innovation policy become to a significant extent blurred in this evolutionary structuralist framework. Reasons are various:

- the actors are interacting at all different levels of the system,
- the practices of diffusion, the incentives and the very activities are not strictly differentiated between science and technology,
- the nature of the produced knowledge is not fundamentally different between science and technology,
- since knowledge is created everywhere in the system, there is no clear functional separation between activities and between actors in the creation of knowledge, transformation of knowledge into innovations, and diffusion of innovations,
- coordination, coherence and complementarities of policy actions are crucial in order to make the overall system better able to learn

Another salient feature of this framework is that government resides within the system. In the mainstream economic framework, government is basically considered as normally placed 'outside' of the market system. Moreover, it is not necessary as far as the markets and behaviors are consistent with the theoretical axioms. Government appears only when some market failures occur. On the contrary, the evolutionary structuralist framework fully recognizes that the government-related institutions and their influences on institutional, technological, social and economic changes as being part of the game. They also act and learn according to the very same basic rules as other actors do. More importantly, they do not necessarily have more knowledge, better cognitive capacity, broader vision, etc. than the other actors in the system. As a consequence, the aforementioned 'learning failures' also occur in the public bodies as well as in the rest of the system.

From this perspective, it is easily recognizable that the 'government failures' are explicitly acknowledged in this evolutionary structuralist framework even though the mainstream economic framework still remains silent. The main source of 'governmental failures' may be the 'gap' between the speed of adaptation of public bodies and the speed of technological and scientific changes in the system. This de-synchronization in the speed of adjustment may have some negative counter-cyclical effects. To avoid such failure in government institutions, they are supposed to not only develop integrative and coherent policy visions, tools, and instruments but also constantly adapt to the new requirements and trends of the economy. This requires the actors in government institutions to be the 'adaptive' policy makers, who permanently try to implement experimental policies, to use different policy instruments, to change the mix of instruments, and to make use of benchmarking approaches as policy learning mechanisms. To make this policy learning mechanism successful, it should encompass another important capability (the so-called 'diagnostic learning') to identify the changes in the environment and the changes in the relative position of actors in this environment at stake.

Reflecting all such aforementioned features, the most serious problem of this evolutionary structuralist framework lies in its complexity, which basically stems from

its systemic and constructivist nature. This complexity prevents to greater extents analysts and policy makers from really envisaging the adequate policy options that would favor the adequate balance of all dilemmas and other trade-offs. Although there have been a great amount of empirical works, they have mostly remained as partial pieces of evidence of the fundamental relevance of this approach mainly because of great levels of complexity and difficulty in defining metrics and tools to operationalize and measure all the concepts in this framework. For instance, they concerns questions such as how to measure some aspects such as diversity and learning capacity even in qualitative terms, what would be a good or satisfying level of the corresponding variable, and what degree of homogeneity in the metrics, scales, or analytical tools should be desirable, and so on. Further, it is more problematic that the mainstream economic framework still dominates the mind of the majority of analysts and policy-makers, although public action has begun to take on new rationale, roles and tasks.

### 3. Comparative Summary

The analyses of the two major frameworks discussed in the above two sections are comparatively summarized in Tables 3. The main features, major theoretical schools, failures and consequences, basic policy principles and their goals, and major problems of each framework are presented side by side.

Table 3. Mainstream Economic Framework and Evolutionary Structuralist Framework

<b>Mainstream Economic Framework</b>	<b>Evolutionary Structuralist Framework</b>
<i>Main Features</i>	
Equilibrium	No Equilibrium
Static Analysis	Dynamic Analysis
Optimizing Rationality	Other forms of Rationality
Input/Output View on Innovation	Interactive model of Innovation
Linear Model of Innovation	Complex Model of Innovation
Optimal Allocation of Resources	Creation of Resources
	Main Resources: Knowledge, dependent on cognitive processes
<i>Theoretical Schools</i>	
Pure Neo-classical Approach	Evolutionary Theory
Transaction Cost Theory	System/Network Approach
Economics of S&T	Knowledge-based Economics
New Growth Theory	
<i>Failures</i>	
Market Failure	Learning Failure
Public Goods: Non-rivalry and Non-Excludability	Exploration/Exploitation Failure
Uncertainty	Selection Failure
Externality	System Failure
	Knowledge Processing Failure

<i>Consequences</i>	
Lack of Incentives for Innovation	Lack of Diversity
Lack of Information	Negative Lock-in
High Cost	Difficulty for Paradigmatic Change
Knowledge/Market/Network Externalities	'Gaps' in society, knowledge, institutions, etc.
<i>Basic Policy Principles</i>	
Reduce Uncertainty	Development and Reorientation of Cognitive Capacity
Substitute Market	Provision of conditions for use of this capacity
Internalization of Externalities	
<i>Policy Goals</i>	
Optimal Allocation by Market Mechanism	Diversity/Selection/Cohesion
Social Optimum	Good Trajectory and Transition
<i>Major Problems</i>	
Government Failure	Complexity in measurements and tools
Asymmetries	Dominance of Mainstream Framework
Linear Model of Innovation	

Despite all such differences between the two frameworks, it should be pointed out that the policy actions derived from both analytical frameworks are neither necessarily different nor antagonistic. Rather they could be complementary to each other in real world. It is crucial to recognize that some policy actions such as subsidy to industrial R&D are apparently common to both frameworks and can be justified on different grounds of each framework. In more detailed practical applications of these policies, though, there may be some obvious differences because they are set up for different purposes.

As it is the case, one may want to use some policy actions for dual purposes by articulating the perspectives provided by both frameworks and justifying them on both

frameworks. For such 'dual use' of policy actions, however, much conceptual and empirical work remains to be done. Furthermore, it entails a critical challenge in evaluating them. The impacts of given dual use policy actions should not be evaluated the same way whether we envisaged them in one framework or the other. Since the policy principles are based on different rationales provided by different theoretical frameworks, they lead to leading to different policy goals and objectives. Accordingly, the evaluation techniques and tools should be based on different evaluation perspectives provided by different theoretical frameworks as well as the evaluation should be done on different objects identified by different theoretical frameworks. Such coherence requirements should be clear when any evaluation exercise is carried out.

It may be also important to note that many policy options empirically developed and exercised borrow their rationales explicitly or implicitly from both frameworks. Ergas's typology on S&T policy orientations (Ergas 1987) is a good example. He distinguished between the mission-oriented policy, which is more likely to be connected to the mainstream economic framework, and diffusion-oriented policy, which is more likely to be rooted in the evolutionary structuralist framework. However, it is also a very plausible circumstance that concentrating the support on a small number of technologies (e.g., critical technologies) or on a small number of larger firms (e.g., Chaebols) is the best way to develop cognitive capacities and enlarge the overall knowledge bases in a country. Conversely, diffusion of information and cooperation are not absent from the mainstream economic perspective. Indeed many policy actions in the real world can be justified from both frameworks.

As for the government roles in creating markets, both frameworks provide quite different perspectives but propose quite similar policy actions. It is obvious that markets play a key role in the mainstream economic framework. But it is also obvious that its role is not completely denied by the evolutionary structuralist framework, in which market is well acknowledged as a decisive element of the selection process. The only difference lies in that the former framework mainly focuses on the creation of demand or supply, the intellectual property rights, and the general operational conditions that are required for creating markets while the latter framework puts more emphasis on the creation of infrastructure and knowledge capacity that are required to make the market exist. This

latter perspective is the consequence of its adoption of a sociologist view of the market, which views market as a social construction involving cognitive capacity.

To conclude, it might be the most important one to point out that it is necessary to combine or synthesize the policies for innovation with other policies for other fields such as competition, education, welfare, etc. in both frameworks. In the mainstream economic framework, the distinction between the different policies is straightforward since each of them can act on a limited set of predefined variables such as incentives, prices, market structure, etc. Whereas, in the evolutionary structuralist framework, the distinction between the different policies becomes less evident since all actions interact at all stages and, because of that, all policies can have a wide range of impacts on the whole system.

#### IV. THE UNITED STATES

This chapter analyzes the science, technology, and innovation (STI) policies in the United States since the World War II in a chronological order. According to the foci of the US policies, we distinguish the period after the WWII into three:

- *Post-war Era* when the US STI policies have mainly focused on ‘science’;
- *1980s* when the focus of the US STI policies has shifted to ‘technology’ to a considerable extent; and
- *1990s and contemporary* when the attentions of the US STI policies has greatly extended to a wide range of activities related to ‘innovation.’

This chronological distinction is however not acute but rather rough in that many of the phenomenal policy issues and actions during each period have often been the outcomes from the prior periods and those even in a period have had the somewhat mixed signals to the science, technology and innovation. Nevertheless, the underlined focus of the US STI policies in each of those chronological periods is evident to a considerable extent so that this chronological distinction seems valid to that extent.

In each chronological period, we attempt to discern its distinct policy foci and principles by analyzing background events and policy actions based on the perspectives provided by the two frameworks, the mainstream economic and the evolutionary structuralist. In particular, we try to link the techno-economic paradigm shifts since the early 1980s to the policy responses taken place during the latter two chronological periods.

## **1. Post-War Era: Science Policy**

The US STI policy during the post-war era up to the mid 1970s can be characterized as the ‘science policy’ since it has focused mainly on the supply-side component, i.e., science. During this time period, based implicitly and more or less explicitly on a simple linear model of innovation, the commercialization of scientific discoveries, that is, the technological development, has been largely considered as the automatic process occurring at the private sector. Meanwhile, based on the strong antitrust tradition, government has been considered to move away from the free market competition and so from the commercial innovative activities, which should be fully left to the hands of private sectors. The exceptions were some crucial missions such as national security, energy, and so on, where government should actively involve in. Consequently, the ‘science,’ which was believed to supply the necessary and sufficient driving forces to the industrial and national innovation, has become the main focus of the US STI policy.

World War II has been the decisive event not only for the emergence of the modern research system in the United States but also for the establishment of such science-oriented policy practices. In particular, the creation and success of the ‘Manhattan Project,’ in which scientists had played a leading role in developing the first fission bombs, was the most dramatic event in establishing many policy principles to be followed later (Smith 1990). While implementing this wartime project, scientific activities in general have been raised to a more prominent position in the defense agencies. In order to fully mobilize the scientific and technological resources for war, the defense agencies have extended their contractual relationships with industry and the universities as well as expanded their laboratories. The practices of relying on universities for research and on industry for development and production were clearly established. The scientist in universities have deeply involved in the creation of large campus laboratories or joined in direct government research projects during wartime. The Office of Scientific Research and Development (OSRD), established at the White House, has coordinated the mobilization of such research efforts and advised the President in setting the policy principles for science.

Largely, this wartime practices have become the basic orientations of the US STI policy after the war. Two prominent orientations have characterized the post-war US policy for science and technology. One was the very active basic science policy, based on a consensus built around the suggestions of the famous report of Vannevar Bush, ‘Science-The Endless Frontier’ (Bush 1945), to the President at the closing phase of World War II. Branscomb (Branscomb 1993) eloquently summarized the quite simple rationales that this report was based on as follows:

“Basic science is a public good. Moreover, investments in science lead to new technologies and, occasionally, new industries. Recognizing the importance of basic science, but also its own inability to direct it, the government entered into a ‘social contract’ with scientists. The government accepted to support scientific research at a much grander scale than ever before, leaving the specifics concerning direction and quality to be decided on the basis of scientific meritocracy (peer review).”

The immediate consequence of this conceptual foundation emphasizing the fundamental importance of basic research was the creation of National Science Foundation (NSF) in 1950. NSF was mandated to ‘promote the progress of science; to advance the national health, prosperity, and welfare, and for other purpose.’ (NSF 2000) Three elements were integrated into the operation of NSF in support of basic sciences (Smith 1990): a) discretionary funding, b) peer review, and c) regional spread. Funds are provided to the investigator or team to cover the direct costs of the specific projects. For selection of research projects, proposals compete on their merits and are judged by those knowledgeable in the particular field. Since bright people were located in universities all over the country, funds are distributed among different regions.

Another orientation was the mission-oriented policy, the active role of several federal agencies for the development of advanced technologies in pursuit of their statutory missions (Ergas 1987). Obviously, the national defense has been the most important mission among others. The dominance of national defense mission has resulted in Department of Defense’s large R&D expenditures that account until recently for more

than half of all government expenditures, and extensive military procurement. In addition, it brought about the creation of many mission-oriented federal agencies including the Atomic Energy Commission (AEC), Advanced Research Projects Agency (ARPA), National Aeronautics and Space Administration (NASA), and the like.

The basic principles of these two policy orientations towards science and technology during the post-war era are well summarized by Branscomb (Branscomb 1993) as follows:

- Federal agencies must aggressively pursue the development of new technology for specific ‘missions’ in activities with extensive public good characteristics, including national defense, nuclear energy, space exploration, and public health.
- The federal government must refrain from ‘picking winners’ through R&D investments directed to technologies for commercial exploitation and specific firms. It is the private sector’s responsibility to try to benefit from government-supported science (and education) and from mission technology spin-offs.
- A further role of the federal government is to create the appropriate regulatory environment to enable efficient markets and occasionally to steer private sector investment in desired directions (for instance, toward environmentally benign technologies). Science and technology can be used to support the struggle against communism.

These principles are basically the supply-side approach. The mechanisms through which government investments in R&D assisted industrial innovation were in accordance with that of a ‘linear’ (or ‘pipeline’) model of innovation. According to such a model, scientific discoveries would inevitably lead to new commercial technologies and mission-oriented technologies would frequently produce spin-offs to civilian sectors. Consequently, the selection of technologies for development and the timing of commercial innovation are left entirely to market forces and government is to avoid being directly involved in private market. Instead, the US policy has largely focused on macroeconomic aspects, which in turn led the US government to shied away from industrial policy and civilian technology policy during the post-war era (Vonortas 2000). Support of basic science, which is believed to fuel the innovation system almost

automatically, has become only the focus of the US policy, resulting in ‘science policy.’

It is obvious that such a supply-side approach is based on the mainstream economic framework, in particular, the pure neo-classical economic theory. As noted earlier, the core of the mainstream economic framework lies in its view of innovative activity as the one performed by individual agent (innovator including firm, government, etc.) using input (investment) to produce a particular good or output (technological knowledge). Such an input-output view of innovative activity is akin to the ‘linear’ model of innovation, in which innovation takes place through the several stages from basic research (science) to applied research, technological development, production, and to marketing. Among these stages, basic research is considered to have the strongest ‘public goods’ characteristics resulting in the weakest private incentives while it is the wellspring of the remaining stages to be followed later. Although very naïve and pure, this conceptual framework provides the exact rationales that government should actively support the basic research while keep away from the private market. Same rationale applies to mission-oriented research, where no private incentives exist, even though it is not necessarily the basic science.

## 2. 1980s: Technology Policy

Dramatic changes in the US STI policy have taken place during the 1980s. Probably, the most decisive force that has induced such policy changes might be the increasing competitiveness pressure from the other economies including Japan, in particular. From mid 1970s and throughout the whole 1980s, there have been strong signs of declining American competitiveness in vital industries such as consumer electronics, automobiles, machine tools, and computers. The signs were strong enough to move even then Reagan administration, which has been in principle hostile to anything that can be labeled to microeconomic management, into action (Vonortas 2000). Three successive Republican Administrations in the 1980s became increasingly convinced that the world had changed for American business and that this necessitated policy changes. They were willing to take the necessary steps to help American business to strengthen its ability to create and deploy technological innovations. The US policy slowly but steadily had moved towards a position of extensive S&T policy modifications. The changed direction has been the one more toward to ‘technology policy’ rather than the traditional ‘science policy.’

A number of major S&T policies have been developed since the late 1970s and throughout the whole 1980s. Several landmark pieces of legislation have prepared the ground for the new policy approach toward innovation. Some were the better-known actions that raised public awareness of the importance of innovation and directly or indirectly provided the foundations of the new policy approach. Table 4 lists these major legislatures.

Table 4. Some Major US Policies in around the 1980s

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***1978 – Domestic Policy Review of Industrial Innovation***

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A Very visible exercise led by the Office of Science and Technology Policy (OSTP) of the White House and the Department of Commerce to examine barriers to innovation.

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***1980 – Stevenson-Wydler Technology Innovation Act***

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Promoted technology transfer from the Federal Laboratories.

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***1980 – Bayh-Dole University and Small Business Patent Act***

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Promoted exploitation of federally funded inventions by industry and universities.

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***1981 – Research and Experimentation (R&E) Tax Credits***

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Congress has (yearly) renewed the tax credits for most of the time period until now and recently extended them to four years.

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***1982 – Small Business Innovation Development Act***

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Authorized the SBIR program requiring agencies spending yearly more than \$100 million on R&D to set aside 0.2% of their funds for small business undertaking early stage, exploratory R&D. The percentage has since risen to 1.25%. It is estimated that the program has made close to 50,000 awards totaling close to \$9 billion in current dollars.

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***1982 – Merger Guidelines***

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New merger guidelines, released by the US Department of Justice and the Federal Trade Commission, dramatically changed a long tradition of progressively stricter antitrust legislation since last in the 19th century.

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***1982 – Eleventh Circuit Court of Appeals for Intellectual Property***

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The establishment of this new court of appeals dramatically increased the effectiveness of enforcement of intellectual property rights in the country.

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***1983 – President’s Commission on Industrial Competitiveness***

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The Commission published its widely publicized report on industrial competitiveness in 1985.

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***1983 – Engineering Research Centers; Industry- University Cooperative Research Centers***

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The National Science Foundation promotes the establishment of both kinds of research centers, requiring industry funding and guidance.

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***1984 – National Cooperative Research Act***

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Following on the steps of the new merger guidelines, this Act was of major importance for

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allowing inter-firm collaboration in research.

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***1986 – Federal Technology Transfer Act***

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Greatly facilitated government-industry cooperation in R&D by establishing the Cooperative Research and Development Agreements (CRADAs) between federal labs and companies.

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***1988 – Omnibus Trade and Competitiveness Act***

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Established the National Institute of Standards and Technology (NIST) which, in addition to the technology laboratories of the earlier National Bureau of Standards, was tasked to oversee the Advanced Technology Program (ATP), the Manufacturing Extension Program (MEP), and the Baldrige National Quality Award. ATP aimed at supporting state-of-the-art technologies with industry funding and guidance. MEP aimed at establishing centers for extending technology to non-R&D intensive firms at all corners of the country. The Baldrige Award aimed at creating a very prestigious and visible instrument to sensitize industry to the importance of high quality standards.

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***1993 – National Cooperative Research and Production Act***

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Extended NCRA (1984) to promote inter-firm cooperation in both R&D and production.

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Source: (Vonortas and Tolnay 2000)

Above and beyond any single piece of legislature or program, the instrumental changes were reflected in a more general shift in orientation concerning the core policies affecting industrial innovation including S&T policy, competition policy, and intellectual property rights policy. Two major steps taken in the 1980s need to have special attentions.

One was the discontinuation of the long-term policies related to competition and intellectual property rights. First, there was a radical change in the philosophy of antitrust (or competition) regulations. It was commenced with the new ‘Merger Guidelines’ issued by the Antitrust Division of the Department of Justice (DOJ) and the Federal Trade Commission (FTC) in 1982. These guidelines were later reinforced with the legislature of the National Cooperative Research Act (NCRA) of 1984. The basic orientation of such

actions was to alleviate the strong antitrust practices especially in the industrial research and development activities. In other words, a strict enforcement of antimonopoly regulations (based on a “per se” approach) was reoriented toward a more relaxed enforcement of antimonopoly regulations (based on a “rule of reason” approach), in particular, in cooperative activities for industrial R&D.

Second, there was also a radical change in the protection of intellectual property rights. This change was culminated in the creation of the 11<sup>th</sup> Circuit Court in the District of Columbia in 1982. By dedicating this Court for the first time to the adjudication of issues related to intellectual property, it intensified to the greater extents the enforcement of existing intellectual property rights laws. That is, a fairly lax enforcement of intellectual property rights laws were reoriented toward a much stricter enforcement of intellectual property rights laws.

Essentially, the long-standing US policies on antitrust and IPR were reversed by these policy actions (Vonortas 1997). These actions were however perfectly in line with the Republican Administrations’ philosophy that the role of the government should be limited to the general economic and regulatory environment in which businesses operate. Although they were forced to accept some rather direct policy measures nudged by the Congress dominated by Democratic Party, they were much less willing to offer direct assistance to civilian technology development.

The other major step taken in the mid-1980s was the initiation of an extensive public debate on economic competitiveness, exemplified by the creation of the President’s Commission on Industrial Competitiveness and its report (President’s Commission on Industrial Competitiveness 1985). Among others, the information technologies, the advanced manufacturing technologies, and the environmental technologies were considered as the areas with strategic importance. It was argued that government intervention was needed for these strategic technological areas or the so-called ‘critical technologies’ because of their significant infrastructural requirements and frequent market failure. Accordingly, the National Information Infrastructure (NII) initiative was put in place. The Defense Advanced Research Projects Agency (DARPA) was renamed to the Advanced Research Projects Agency (ARPA) and its mission was refocused on

dual-use technologies. Government laboratories (many of them as part of the Department of Energy's research system) were strongly induced to set up Cooperative R&D Agreement (CRADAs) with industry. Manufacturing R&D was promoted through collaborative agreements with the private sector, which were enabled by an increasingly relaxed antitrust regulatory system.

Such public debates on competitiveness have later culminated in the passing of the Omnibus Trade and Competitiveness Act in 1988. This was an important piece of legislation, which basically forced then Bush Administration to accept. Among many other provisions, it radically changed the nature of a little known agency known as the National Bureau of Standards (NBS). It renamed NBS into the National Institute of Standards and Technology (NIST) and transformed it into a much more formidable agency absorbing the newly established programs such as the Advance Technology Program (ATP), the Manufacturing Extension Program (MEP), and the National Baldrige Quality Award (NBQA) as additions to its long-standing laboratories for industrial standards. ATP aimed to support the state-of-the-art technologies with industry through funding and guidance. Through MEP, many research centers were established for accelerating the technology diffusion to non-R&D intensive firms at all corners of the country. NBQA created a very prestigious and visible instrument to sensitize industry to the importance of high quality standards.

These actions taken through the competitiveness debates were more direct measures that were forced to accept by then majority Democratic Party but were willing to accept by then Republican Administrations. Besides the aforementioned actions, much wider range of policy measures were introduced during the 1980s. They include the R&E tax credit established in 1981 and the SBIR program established in 1982. The current Bush Administration attempts to make the R&E tax credit permanent after several renewals. The required percentage set aside for support of the SBIR program by all federal agencies with R&D budget has been rapidly increasing from 0.2% to 1.25% during last two decades.

In any rate, it seems obvious that greater attention has been paid to the demand-side element, i.e., 'technology.' The support for basic science has continued even in 1980s.

Facing the competitiveness crisis, however, the major focus of the US policy has radically moved from 'science' to 'technology.' For this, we may arguably characterize the US STI policy in 1980s as the 'technology policy.'

Nevertheless, the rationales, on which this changed orientations of the US policy have based, still remain within the mainstream economic framework. The concept of 'market failure' provided by the mainstream economic framework has played an enormous role in justifying the individual policy measures. For example, the enforcement of intellectual property rights law was the typical remedy for restoring private incentives for industrial R&D activities. In addition, the relaxation of strong antitrust tradition, which consequently leads to the enforcement of cooperation in industrial R&D, was justified on the basis of more refined theory of generic or precompetitive research. Some more direct measures (e.g., ATP or Critical Technology) resulted from competitiveness debates have been controversial but to a greater extent excused essentially within the mainstream economic framework.

### **3. 1990s and Contemporary: Innovation Policy**

Taking office in the early 1990s, the Clinton Administration has reinforced the policies of its predecessors and added some new, more interventionist, policy instruments. More importantly, it also added a strong vision of a more balanced supply-side/demand-side technology or innovation policy. Perhaps the most significant contribution of the Clinton Administration might be its strong signal to American industry of a government seriously concerned with the need to foster technology for economic growth. Such policy actions have largely raised public awareness of the importance of innovation and prepared the ground for this new Democratic Administration with a very aggressive science and technology policy agenda.

“American technology policy must move in a new direction to build economic strength and spur economic growth. The traditional federal role in technology development has been limited to support of basic science and mission-oriented research in the Defense Department, NAS, and other agencies. This strategy was appropriate for a previous generation but not for today’s profound challenges. We cannot rely on the serendipitous application of defense technology to the private sector. We must aim directly at these new challenges and focus our efforts on the new opportunities before us, recognizing that government can play a key role in helping private firms develop and profit from innovation.” (White House 1993, p.1)

Under this declaration of reorientation of technology policy, several objectives were clearly stated as follows (White House 1993, p.1):

- “Strengthening America’s industrial competitiveness and creating jobs;
- Creating a business environment where technical innovation can flourish and where investment is attracted to new ideas;
- Ensuring the coordinated management of technology across all agencies of the government;
- Forging a closer working partnership between industry, the federal and state

- governments, workers, and universities;
- Redirecting the focus of national efforts toward technologies crucial to today's businesses and a growing economy, such as information and communication, flexible manufacturing, and environmental technologies; and,
- Reaffirming our commitment to basic science, the foundation on which all technical progress is ultimately built.”

Although such a grand vision and these policy objectives resulting from grand vision set out to implement a seemingly radical policy shift, neither the justification for this shift nor the specific instruments to achieve the main policy objectives were entirely new. The 'new' policy orientation reflected issues and solutions that had been debated for years. It were already proposed and debated in a significant number of reports that were produced during the 1980s stressing the need for radical policy change. Even as far back as the late 1970s, President Carter's science advisor had considered several similar ideas.

Nevertheless, several of these objectives point to a radical shift to a considerable extent from the traditional US policies. (Branscomb 1993) characterized the some basic principles of this new S&T policy declared under the Clinton Administration since early 1990s as follows:

- The government partly shifts its priorities from large government missions toward assisting the technological prowess and international competitiveness of the private sector. National defense cannot anymore be driving technologies in many cutting-edge fields. Government agencies are encouraged to buy off-the-shelf, state-of-the-art technologies from the private sector. Agencies with significant S&T budgets should try to develop, to the extent possible, dual-use technologies.
- The government must try to balance the supply and demand sides of its technology policy. That is, in addition to the creation of new technologies, significant weight must be placed on technology dissemination. The government must pay attention to the ability of firms to locate, access, adapt, and use new technologies.
- State governments must increase their role in the national technology policy. At a

- minimum, they must be prepared to assist smaller firms, attract capital, and diffuse innovation-related knowledge (e.g., manufacturing extension services).
- An increased dialogue with industry is necessary to assist the government in making decisions with respect to civilian technologies. Specific technology policy goals can be frequently pursued through public/private cooperative R&D undertakings.
  - A more relaxed antitrust environment allows firms to enter multiple strategic alliances to allay the pressures from increased international competition and to assist them in responding to the demands of rapidly changing technologies. Multi-firm research joint ventures for precompetitive and infrastructural R&D must be favored.
  - An increasingly stringent enforcement of intellectual property rights by the court system promotes the creation and rapid commercialization of new technological knowledge for the competitiveness of American industry. Intellectual property matters can be linked with the efforts of the US Trade Representative office to ensure a 'level playing field' for American companies in foreign markets.
  - The system of national laboratories should increase their interaction with the private sector in order to expedite the transfer of innovation-related knowledge and facilitate large-scale, heavy facility-dependent R&D.
  - The research universities must also interact more with the private sector. This will both create an alternative source of funds for the universities and will speed up the commercialization of good science to benefit industry.
  - Large science projects should be increasingly funded and undertaken cooperatively with other countries.

These policy principles indicate that innovation, rather than just technology, has become the major target of the US STI policy since the early 1990s. That is, the major focus of the policy has shifted from the heavily demand-oriented 'technology' or heavily supply-oriented 'science' to the 'innovation' that seeks a better balance between supply- and demand-oriented (technology-user-oriented) factors, which requires much more comprehensive approaches. A large number of programs were introduced during 1993-1994 to implement the new policy principles. In addition, existing initiatives relating to civilian technologies were given significant boost. Well-known examples of new or

enhanced programs include the Advanced Technology Program (ATP), the Technology Reinvestment Program (TRP), the Environmental Technology Initiative (ETI), the Manufacturing Extension Partnership (MEP), the Partnership for a New Generation of Vehicles (PNGV), the Small Business Innovation and Research (SBIR) program, and much later the National Nanotechnology Initiative (NNI).

The primary forces leading to such a shift in the US policy orientation since the early 1990s might be the gradual recognition of emergence of the knowledge-based economy and a better understanding of the innovation process. Irrespective of specific programs and policy measures, one thing abundantly clear and increasingly clearer is that there is much more awareness in all government strata today of the changing international environment of industrial technology and innovation, and the place of US business in it, than ever before. The manifestations and effects of some key technologies, the emergence of the knowledge-based economy, and the powerful effects of globalization are on the minds of contemporary policy decision-makers. Also much clear is the change in society's basic perception of high technology from the output of R&D-intensive manufacturing industries to a style of work applicable to almost every industry. This change is said to have revolutionized the features of successful technology policy, focusing it more on the distribution of knowledge, skill, entrepreneurship, and the facilitation of new forms of partnering between firms, universities, and the government.

It is obvious that many works and refinements under the evolutionary structuralist framework have greatly contributed to enabling such better understanding of innovation process and recognition of paradigm shift including emergence of knowledge-based economy, technological advances in some key areas, and globalization. Many of specific policy measures in 1990s and in more recent years are just continuums of previously initiated ones. However, they are now viewed from different perspective and evaluated on different criteria. All these reflect the perspective of the evolutionary structuralist framework to a significant extent.

## **V. Korea**

[This part will be prepared and incorporated at STEPI.]

## **VI. Conclusion: Policy Implications**

We have analyzed the techno-economic paradigm shift that has begun in last 1970s, rapidly developed throughout the 1980s, and is currently still proceeding from the various aspects. The first and foremost driving impetus of this shift might be the rapid advances in information and communication technologies (ICTs) and other key infrastructural technologies including biotechnology, new materials technology, and in more recent years nanotechnology. While these technological advances have intensifying globalization, they have coupled with such intensifying globalization to drive the old economy shift toward the so-called 'knowledge-based economy (KBE)' by inducing the dramatic and profound changes in the structures of industrial governance. Subsequently, there have been great efforts to adjust the government policies for innovation to this new emerging economy, the KBE. All these rather dramatic and profound changes together have induced techno-economic paradigm shift.

We have also analyzed two major frameworks, the mainstream economic framework and the evolutionary structuralist framework, that surround debates on the rationales to justify the policy actions for innovation. They are quite different in their diagnoses and prescriptions on innovation according to their different perspectives. Despite all such differences, the policy actions derived from both analytical frameworks are often complementary rather than antagonistic since some policy actions are pretty common in both frameworks. However, it should be underlined that since each framework provides different policy goals and objectives on the basis of its own rationales even if the same policy action, quite different approaches, tools, and techniques should be adopted for evaluating them. All in all, the analysis on the two major frameworks for government STI policy teaches us that, whichever frameworks we are based on, it is important and necessary to approach to science, technology, and innovation in a comprehensive manner. In other words, the policies for innovation should be combined with other policies such as general macroeconomic, education, environmental, welfare, and so on.

From such discussions, one important implication that can be drawn for both countries,

Korea and the United States, might be that the contemporary STI policies are not be justified by just one concrete scrutinized rationale but can have various sources for their justification. More importantly, they should be justified within a specific system because they are context-dependent to a greater extent.

From this perspective, the implications should be divided for Korea and the United States. They are related to the current circumstances of national innovation systems. For Korea, diversity should be much more emphasized since its system has consistently shown very centralized characteristics. For the United States, integration should be stressed with a more significance since its system has often revealed fragmented features. On such an aspect, we may find some possible areas that both countries can learn from each other and cooperate with each other.

Nonetheless, one last and the most important implication from the prior analyses is that the contemporary STI policies are demanded to integrated or be integrated with other policies including economic, education, welfare, national security and so on. In this respect, each country has already made great efforts such as committees or offices established directly under President to coordinate and harmonize various aspects of policies. From this same exact respect, however, Korean government may go further to cautiously consider the so-called 'constructive destruction' of the Ministry of Science and Technology (MOST) and having the S&T experts permeate into the other government agencies and play the critical roles in developing more innovation-oriented policies in their areas.

## References

- Anton, P. S., R. Silbergitt, et al. (2001). *The Global Technology Revolution: Bio/Nano/Materials Trends and Their Synergies with Information Technology* by 2015. Santa Monica, CA and Arlington, VA, RAND: 69.
- Branscomb, L. M., Ed. (1993). *Empowering Technology : Implementing A U.S. Strategy*. Cambridge, MA, The MIT Press.
- Bush, V. (1945). *Science - The Endless Frontier : A Report to the President on a Program for Postwar Scientific Research*. Washington, DC, National Science Foundation.
- Ergas, H. (1987). *Does Technology Policy Matter? Technology and Global Industry: Companies and Nations in the World Economy*. B. R. Guile and H. Brooks. Washington, D.C., National Academy Press: 191-245.
- Foray, D. and B.-A. Lundvall (1996). *The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy. Employment and Growth in the Knowledge-Based Economy*. D. Foray and B.-A. Lundvall. Paris, OECD.
- Gera, S. and R. Hirshhorn (2000). "Policies for Promoting the Development of Knowledge-based Economies: The APEC Experience." *Journal of APEC STUDIES* 2(1): 151-185.
- Gramlich, E. M. (1990). *A Guide to Benefit-Cost Analysis*. Englewood Cliffs, Prentice Hall.
- ITAG and Ernst & Young (1999). *The Knowledge Economy, Information Technology Advisory Group*.
- IWGN (2000). *National Nanotechnology Initiative: Leading to the Next Industrial*

- Revolution. Washington, DC, Interagency Working Group on Nanoscience, Engineering and Technology (IWGN) of the National Science and Technology Council's Committee on Technology: 100.
- Jang, Y. (2000). Comparative Analysis of Industrial R&D Cooperation in Korea and the United States. Columbian School of Arts and Sciences. Washington, DC, The George Washington University: 208.
- Kendrick, J. W. (1994). "Total Capital and Economic Growth." *Atlantic Economic Journal* 22(1).
- Kline, S. J. and N. Rosenberg (1986). An Overview of Innovation. The Positive Sum Strategy. R. Landau and N. Rosenberg. Washington, DC, National Academy Press: 275-305.
- Kodama, F. (1988). The Six Paradigm Changes in Science and Technology Policy. Seminar on Science and Technology Policy, Seoul, Korea.
- Kodama, F. (1995). Emerging Patterns of Innovation: Sources of Japan's Technological Edge. Boston, MA, Harvard Business School Press.
- Lundvall, B.-A. (1997). Development strategies in the learning economy. Seoul, paper submitted a STPI's 10th Anniversary Conference.
- Lundvall, B.-A. and S. Borrás (1999). The Globalising Learning Economy: Implications for Innovation Policy. Luxembourg, European Commission, Directorate-General XII (Science, Technology and Development).
- Lundvall, B.-A. and B. Johnson (1994). "The Learning Economy." *Journal of Industrial Studies* 2: 23-42.
- McKeon, R. and T. Weir (2000). "Towards Knowledge-based Economies: Preconditions and Assessments." *Journal of APEC STUDIES* 2(1): 131-149.

- Metcalf, J. S. and L. Georghiou (1998). "Equilibrium and Evolutionary Foundations of Technology Policy." STI Review Special Issues on "New Rationale and Approaches in Technology and Innovation Policy"(22): 75-100.
- Nelson, R. R. (1989). "What is Private and What is Public About Technology?" Science, Technology, & Human Values 14(3): 229-241.
- Nelson, R. R. (1990). "Capitalism as an engine of progress." Research Policy 19: 193-214.
- NSF (1998). Science and Engineering Indicators 1998, National Science Foundation.
- NSF (2000). Science and Engineering Indicators 2000. Arlington, VA, National Science Foundation.
- OECD (1996). Globalization and Competitiveness: Relevant Indicators. Paris, Directorate for Science, Technology and Industry: 60.
- OECD (1996). The Knowledge-Based Economy. Paris, Organization for Economic Cooperation and Development.
- OECD (1998). Internationalization of Industrial R&D: Patterns and Trends. Paris, Organization for Economic Cooperation and Development: 107.
- OECD (2000). Current and Emerging Policy Issues Arising from Biotechnology. Paris, Organisation for Economic Cooperation and Development: 15.
- OECD (2000). OECD Science, Technology and Industry Scoreboard 2000. Paris, Organization for Economic Cooperation and Development.
- OECD (2000). The Service Economy. Paris, Organization for Economic Cooperation and Development.

- OECD (2001). *The New Economy: Beyond the Hype Final Report on the OECD Growth Project: Executive Summary*. Paris, Organisation for Economic Cooperation and Development: 26.
- Ouchi, W. G. (1989). "The New Joint R&D." *Proceedings of the IEEE* 77(9): 1318-1326.
- Ouchi, W. G. and M. K. Bolton (1988). "The logic of joint research and development." *California Management Review* 30(Spring).
- President's Commission on Industrial Competitiveness (1985). *Global Competition: The New Reality*. Washington, DC, U.S. Government Printing Office.
- Rosenberg, N. (1990). "Why do firms do basic research (with their own money)?" *Research Policy* 19: 165-174.
- Smith, B. L. R. (1990). *American Science Policy Since World War II*. Washington, DC, The Brookings Institution.
- Teece, D. J. (1989). "Inter-Organizational requirements of the innovation process." *Managerial and Decision Economics*(Special Issue): 35-42.
- Vonortas, N. S. (1997). *Cooperation in Research and Development*. Boston/Dordrecht/London, Kluwer Academic Publishers.
- Vonortas, N. S. (2000). "Technology policy in the United States and the European Union: Shifting orientation towards technology users." *Science and Public Policy* 27(2): 97-108.
- Vonortas, N. S. and A. Tolnay (2000). "Towards the Knowledge-based Economy: United States and its APEC Partners." *Journal of APEC STUDIES* 2(1): 187-229.
- White House (1993). *Technology for America's Economic Growth: A New Direction to*

Build Economic Strength. Washington, D.C., White House.

Williamson, O. E. (1991). "Strategizing, Economizing, and Economic Organization."  
Strategic Management Journal 12: 75-94.