CHAPTER 19

On Innovation Strategies: an Asian Perspective

Nam P. Suh

INTRODUCTION

Innovation has become the buzzword of the 21st century and even more so now after the current economic meltdown, as nations around the world have the enormous task of rebuilding their economies. It is generally agreed that innovation refers to the process of converting an idea, invention or scientific discovery into commercially or publicly successful products, processes, services or systems that improve the way we do things.

Societal needs often spark innovation. Today, job creation, economic growth and solutions to urgent problems related to energy, environment, water and sustainability (EEWS) require innovative solutions. Some of the needs for innovation are common to all nations, but specific issues entailed in these problems can be regional in scope.

Innovation is particularly imperative to the future economic and social health of the industrialized nations of Asia. Except for China, these nations have limited natural resources. Their economies have depended on the export of manufactured goods, including ships, cars, steel, semiconductors, computers and television sets. Their trade surplus over the past decade is a testimony to their global dominance in manufacturing. Yet, these countries did not invent or innovate many of the products for which they are known. Rather their competitive strengths are derived from the quality of their products and manufacturing technologies.

This paper reviews the current status of innovation and innovation-related activities in China, Japan and Korea, with a greater emphasis on Korea. This paper will dissect the innovation strategies, identify important issues that affect innovation and discuss possible means of strengthening the innovation process.

There are many questions related to innovation we should answer. In order to provide a common metric for understanding innovation strategies and processes, innovation strategies will be discussed based on a theory of innovation in order to provide a generalized conceptual framework (Suh, 2009).

NATURE OF INNOVATION

The literature on innovation is rich with historical examples, case studies, ad hoc claims, and generalizations (OTA, 1984; Drucker, 1985; Utterback, 1996; Branscomb *et al.*, 2001; Gray, 2004; Nelsen, 2005, Scotchmer, 2006; Welfens *et al.*, 2008).

To understand the nature of innovation, we need to answer some basic questions, such as:

- Why aren't there innovation hubs in Kansas City, Missouri, USA?
- Why are there only a few innovation hubs in the world?
- Why aren't there major innovation hubs — similar to those in the Silicon Valley or Boston, U.S. — in Europe and Asia?
- What do we have to do create an innovation hub?
- What should educational institutions do to generate people who can innovate?

The ability to innovate depends on many specific factors, such as GDP, GDP per capita, expenditure for R&D, the state of industrial development, the quality of education, cultural tolerance for risk taking and politics. However, innovation is not a result of a random process, although sometimes they follow an unpredictable path. Depending on how it is done, the effectiveness and efficacy of R&D investment in creating disruptive innovations can vary between different nations and even between different regions of a country. This paper will attempt to answer the questions posed above and generalize the requisite conditions for innovation based on the three laws of innovation (Suh, 2009).

THREE LAWS OF INNOVATION

The theory of innovation (Suh, 2009) states that there are three laws that govern the innovation process. These laws are based on the three requisites that are essential in innovation processes: innovation continuum, nucleation of innovation hubs (or equivalent entity) and the dominance of the nucleation rate over the diffusion rate.

The three laws of innovation are stated as follows:

The First Law: *For innovation to occur, there cannot be any missing steps or elements in the innovation continuum.*

The Second Law: Innovation occurs more readily around an innovation hub, which nucleates when sufficient innovation activities are present to create a nucleate that is larger than the critical size needed for stability and to overcome the activation energy barrier for innovation.

The third law: For innovation hubs to nucleate, the nucleation rate of innovation in a region must be greater than the rate at which innovative ideas, people and financial resource can diffuse or move away from the region.

BASIS OF THE INNOVATION LAWS

Definition of Innovation Continuum?

An innovation is a result of undertaking many steps or activities. Initially there may be many ideas for research or many inventions, one of which ultimately becomes a successful innovation (in the form of product, process, systems and service). The essential steps are different depending on the nature of innovation, but some of the common steps may be listed as follows (Suh, 2009):

1. Identification of the need.
2. Basic research.
3. Creation of ideas.
4. Demonstration of the feasibility.
5. Testing of commercial viability.
6. Finding an "angel" who will be willing to fund #4 and #5.
7. Raising venture capital or finding a large company that is willing to develop the idea.
8. Creation or identification of a venture company that can manufacture and sell the product.
9. Hiring talented people for all functions the company must perform.
10. Raising capital for the new venture firm through initial public offering.
11. Selling of the venture company.

These (or equivalent) steps form an innovation continuum from the inception of an idea to its transformation to commercial products. Some of these steps may not be required when it is done in a large company. When one or more of the essential steps of the innovation continuum are missing, the probability of success for innovation decreases significantly.

When the first law of innovation regarding the innovation continuum is not satisfied, innovation cannot proceed. Even after the first law is satisfied, the second law of innovation, which deals with nucleation of an innovation hub, must also be satisfied.

Nucleation of Innovation Hubs

The fact that all the steps of the innovation continuum are in place does not guarantee the nucleation of an innovation. The existence of an innovation continuum is necessary, but it is not sufficient. Innovation occurs more readily if there is an existing innovation hub or a large industrial complex that is willing to develop new ideas. For example, Boston is an innovation hub for biotech. It is easier to start a biotech company in Boston than elsewhere. The large shipbuilding industry of Korea can also be an innovation hub for marine-related products.

One way of enabling innovation is to nucleate an innovation hub. Another way is to induce a heterogeneous nucleation around an existing innovation hub. Heterogeneous nucleation of innovation around an existing hub, à la Silicon Valley, is much easier than homogenous nucleation of a new hub.

In the absence of a pre-existing innovation hub, an innovation hub must be established first through homogenous nucleation. Once an innovation hub exists, heterogeneous nucleation of new innovations can occur around the existing hub. When there is a large industrial base, it can act as a hub and heterogeneous nucleation of innovation can occur around the industry.

The nucleation of innovation hubs is analogous to the nucleation of rain droplets in the atmosphere. When rain droplets form by condensation of water vapour in the absence of any existing particle, it is called homogeneous nucleation. When there are particles, such as previously nucleated water particles or impurity particles in air, the condensation forms around the existing particle by heterogeneous nucleation. Heterogeneous nucleation on an existing particle is energetically more favoured. Therefore, heterogeneous nucleation occurs at a higher rate than homogeneous nucleation.

For homogeneous nucleation to occur, the nucleated entity (e.g., a water droplet formed from the vapour phase) must be larger than a critical size to be stable. If it is smaller than the critical size, the nucleate will go back to its original state, i.e., a water droplet smaller than a critical size evaporates back to vapour. It is difficult to nucleate an innovation hub with only a limited number of innovations. It is much easier if there are tens or hundreds of ideas and activities available for innovation.

When a nucleate formed is larger than the critical size, it grows because the vapour condenses by heterogeneous nucleation on existing droplets rather than nucleating a new droplet. This process makes the nucleate that formed first grow faster than the one formed later. This is the reason why it is easier to nucleate an innovative idea around an existing hub rather than homogeneously nucleate a new one.

This discussion on homogeneous versus heterogeneous nucleation implies that once China, Japan and Korea form innovation hubs, the subsequent innovation processes in these countries will accelerate. In other words, it is difficult to get the innovation hub started, but once it is established, it is fairly easy to sustain the generation of innovations by heterogeneous nucleation. Then the number of innovations may explode exponentially, increasing new innovations.

To better understand the innovation process, the nucleation rate of innovations may be modeled as a rate equation:

$$\frac{dI}{dt} = I_o f_I \exp\left(\frac{-\Delta G}{bH}\right)$$

where I is occurrence of innovation, t is time, the product $I_o f$ is a constant with a dimension of "innovation per unit time", ΔG is the activation energy that needs to be overcome to innovate, and the product bH is a constant that represents the overall energy of innovation activities. The exponential function represents the probability of creating an innovation. ΔG of homogeneous nucleation is larger than that of heterogeneous nucleation, indicating that the creation of new innovation hubs is inherently more difficult than a heterogeneous nucleation on an existing site. Based on this rate model and an energy argument, we can show that there is a critical size of a nucleate below which the innovation hub cannot form.

The second law of innovation may be stated as follows:

The rate of innovation is greater when there are more innovative activities that can overcome the activation energy barrier for innovation. (Corollary: Innovation occurs more readily around an innovation hub, which nucleates when the initial nucleate size exceeds the critical size needed for stability and if the innovative activities can overcome the activation energy barrier.)

Diffusion of Innovative Ideas vs Nucleation of Innovation

Once an innovation hub exists, it tends to grow as new innovative ideas from other regions, as well as from the near-by regions, diffuse to the site and nucleate by heterogeneous nucleation. Ideas and people with innovative ideas can move to an existing hub rather than nucleating a new innovation hub. Therefore, there is a competition between homogeneous nucleation of an innovation hub and the diffusion of ideas and people away from a region with no hub to an existing innovation hub. That is the reason why it is difficult to create new innovation hubs like Boston. About 50% of the revenue of Silicon Valley companies is from Stanford spin-off companies, but, of more than 1,000 companies that were spun-out from Stanford University, only one out of 20 companies used the technologies that came out of Stanford. Many ideas came to Silicon Valley from other regions (Byer, 2006).

In Asia, there are no innovation hubs that are equivalent to Boston or Silicon Valley. Unless nations in Asia can create innovation hubs or provide an equivalent site for heterogeneous nucleation, people with innovative ideas will emigrate to California or Boston.

In countries where large companies dominate the industry and control a large fraction of GDP, it is sometimes much more difficult for entrepreneurs to establish innovative companies. In these countries, creative people work for a large company that provides job security rather than start their own business or work for new venture firms.

The third law of innovation may be stated as follows:

To nucleate an innovation hub in a given region, the nucleation rate of innovation in the region must be greater than the rate at which innovative ideas, creative people and financial resources can diffuse away from the region to an existing hub.

MANUFACTURING, ECONOMY AND INNOVATIONS IN ASIA

During the past several decades, four Asian nations — Japan, Korea, Taiwan and China —have successfully developed their national economies by manufacturing well-established products competitively in large volumes for the worldwide market. To become major manufacturing nations, they have adopted and improved existing technological paradigms and methods rather than innovating new products or systems that are uniquely of their own.

In 2009, people in countries across the world are living in uncertain times because of the unprecedented and largely unanticipated global economic turmoil. Asia is no exception. The current economic crisis poses opportunities as well as risks for China, Japan and Korea. Their ability to innovate will affect the future development and competitiveness of these countries, which will augment their traditional strength in manufacturing.

The overall impact of the current economic downturn appears to be milder in Asia than in the United States. Nevertheless, it has had major impact on economies of the Asian countries. China has lost 20 million jobs and its unemployment rate in 2008 reached 9.0%. In January 2009, its export decreased by 17.5% year-on-year to US$90.45 billion and its imports by 43.1% to US$51.34 billion. Korea has lost jobs as well, although to a less extent than many other countries; its unemployment rate in February 2009 was 3.5%. The Korean currency had lost as much as 60% of its value relative to the U.S. dollar within a few months upon the collapse of the stock market. Since then, it has recovered; as of June 2009, it is down about 25%. The depreciation of the Korean currency has improved the global competitiveness of Korean products. In December 2008, exports from Korea fell 17.4% to US$27.29 billion, while imports dropped 21.5% to US$26.62 billion. On the other hand, the Japanese currency appreciated in value, which has devastated their export industry. Its industrial production decreased by 30.1% from

January 2008 to January 2009. The unemployment rate in Japan stood at 4.1% in January 2009. All three countries are trying to revive their economy by injecting liquidity into their banking systems, increasing domestic consumption and the export of goods, creating jobs and stabilizing the real estate market.

Innovation has been a hot topic in Korea. In 2008, the Korean government created a planning commission (chaired by the author) to identify technologies and industries that could become "new economic growth engines". Some 360 experts participated in the planning exercise and identified 21 technologies. In September 2008, the government adopted 17 of these fields as the priority areas for R&D investment by the public and the private sector.

Two of these projects — On-Line Electric Vehicle (OLEV) and Mobile Harbor (MH) — are being led by KAIST. These products may become paradigm-shifting major innovations, if successful.

STATUS OF INNOVATION IN KOREA, JAPAN AND CHINA

China, Japan and Korea are similar in that they do not have innovation hubs. However, there are significant differences amongst them in terms of GDP per capita, R&D investment, technological levels and political structure (OECD, 2008).

Korea

Korea is a leading nation in many industrial sectors: shipbuilding, DRAM, cell phones, LCD displays, automobiles, desalination, nuclear power plants and steel. Its IT infrastructure is one of the most advanced among all nations. Yet Korea cannot claim to be one of the most innovative countries in the world.

The relative lack of innovation in Korea cannot be attributed to its R&D spending. In 2007, Korea invested 3.47% of its GDP in R&D, the public sector expenditure being 26.1% of the R&D investment. In 2008, about 5% of the government budget was for R&D. As a percentage of its GDP, its R&D spending is about the same as Japan, and its educational spending per capita is comparable as well, although its GDP per capita is substantially less than that of Japan and much larger than that of China. Korea is increasing its R&D budget at a higher rate than many other countries. What Korea has to do is to increase the rate of innovation for the R&D investment made.

The Korean government has invested a significant amount of R&D funds in national laboratories and universities, and has created Science Park in Daejeon City, which is home to some 30 national laboratories, about an equal number of industrial research laboratories and KAIST. The Daedeok Science Park and its adjacent area have several thousand Ph.D.s. The question is why this area has not become an innovation hub.

The government has invested US$3 to US$4 billion per annum in the national laboratories in the Daejeon Science Park. This investment is comparable to the R&D investment made in the greater Boston area of the U.S. by the U.S. National Institute of Health (NIH), which was about US$ 2 billion in 2005 (Nelsen, 2005). This annual NIH investment has created about 350 biotech firms and 150 medical device companies in the Boston area. They employ about 30,000 people. The market cap of the top ten biotech companies was about US$85 billion in 2005. However, the comparable investment made in the Daejeon area has not yielded a comparable degree of innovations and financial returns. Why is there the difference between Boston and Daejeon?

The difference between Boston and Daejeon may be attributed to the fact that Boston satisfies the three laws of innovation, whereas Daejeon does not. Unlike Boston, Daejeon has many missing elements in its *innovation continuum* such as venture capital firms, easy access to the global market and global visibility. It has a limited number of venture capitalists and risk-takers who are willing to convert research results into innovations. Also the research institutes in the Daedeok Science Park might have chosen research projects to increase the number of publications rather than choosing challenging topics that address real societal needs. Also the R&D funding is too fragmented among different research institutes, supporting many small and diverse projects rather than developing systems solutions to satisfy real societal needs. Therefore, for Daejeon to become an innovation hub, it must fill in the missing steps of the innovation continuum and create innovative activities that can overcome the activation energy barrier for nucleation.

In education, which provides the basic foundation for innovation, Korea has been investing heavily and has done well (for example, Korean high school students rank near the top in math and science in the world.) In 2008, the Korean government spent 20% of its budget on education — 11% of which was for tertiary education and 88% for K-12 education. More than 84% of high school graduates go on to colleges and universities in Korea, which is just the inverse of the situation in Switzerland (Eichler, Chapter 8). Korea's K-12 educational system has been criticized for focusing too heavily on preparing students for college entrance examinations. Nearly 50% of Korea's investment in education is for private tutoring and cram schools.

In 1972, the Korean government created the Korea Advanced Institute of Science and Technology (KAIST) to educate scientists and engineers with advanced degrees to augment its investment in heavy industries. KAIST is now the leading university in Korea and is ascending in the ranking of world's best universities. Its engineering program was ranked to be the 34th in the world by the *London Times* supplement in 2008. KAIST has outstanding professors and excellent students. About 70% of KAIST students come from the 20 "Science High Schools" of Korea, which collectively produce about

2,000 graduates a year — academically the top 0.1% of all high school graduates. It also accepts nearly all of the graduates (about 140 a year) of the Korea Science Academy, known as the high school for genius. KAIST's Ph.D.s populate leading industrial firms and universities. KAIST is the home for many innovations such as humanoid robots, new materials, IT products, and others. To innovate major products and advance science and technology, KAIST has established internal research funds entitled "HRHR" (high risk, high return) to enable faculty members and graduate students to conduct preliminary research on innovative ideas and secure intellectual property rights (IPR) before they seek outside support. KAIST also funds innovative research in the fields of EEWS (energy, environment, water and sustainability). KAIST is developing electrical cars — OLEV — that receive electric power from an underground cable. It is also developing a mobile harbor — MH — that will eliminate the need for major harbors, reduce the ground transport systems, and decrease the environmental damage caused by trucks.

Korean educational institutions may become more competitive in the future because of the recent reforms made at KAIST. KAIST has instituted major changes, including the strict tenure system for faculty, tuition for students with low grade point average, and evaluation of faculty performance by experts from both inside and outside Korea. KAIST measures the performance of its faculty based on the impact made by research rather than the number of publications. KAIST promotes "bi-modal thinking" — the ability to think both in the domain of synthesis and analysis. To achieve this goal, a design course is required of all freshmen. KAIST has also launched the Renaissance Ph.D. Program that consists of two years of design of complex systems, followed by three years of analysis of the systems they designed. KAIST will become all English-instruction campus in 2010. Some of the universities in Korea are following KAIST's lead, instituting similar reforms.

Japan

Japan is the most technologically advanced nation among the four Far East Asian nations. Its economy is the second-largest in the world and has dominated many areas of manufacturing technologies. Japan supplies many key components to industrial firms in Korea, China and other countries.

Rather than being the first to innovate, Japan's forte has been improvements on major innovations first introduced in other countries. Japan has made many studies on Japan's innovation and innovation strategies (e.g., National Research Council, 1999). Like Korea, Japan has also invested heavily in national laboratories, with mixed results. To improve the performance of national laboratories, Japan merged 26 of the laboratories and established the Advanced Institute of Science and Technology (AIST). Their goal is to innovate new technologies that are far more advanced than current industrial technologies.

The Japanese higher education system consists of public and private universities, similar to the situation in the U.S. and Korea. National universities have been controlled by the government ministries and are highly regulated. Professors in these national universities are civil servants. To make universities more competitive and innovative, Japan is in the process of privatizing its national universities. However, to make Japanese universities more competitive, they may have to change their R&D funding system to concentrate their major R&D investment in a limited number of carefully selected universities on a long-term basis. They may also have to change the system of university governance to make it more flexible and adaptable.

A committee on Japan's Innovation Strategy states the following (Doyukai, 2006): "One main factor that is impeding Japan's ability to innovate is its rigid social structure which deters change, a side effect of Japan's successful post-war economic revival. Another factor is Japan's homogeneous society, which resents those who stand out and is at the root of an often closed and jealous mind-set." The committee recommended the following three strategies for building a society that encourages innovations:

1. The first strategy is to build an open society.
2. The second strategy is to build a diverse society.
3. The third strategy is to build an attractive society that people can be proud of.

In terms of the three laws of innovation, Japan may have all the elements that constitute the innovation continuum. However, at a local level, the innovation continuum may have missing steps. Also the activation energy for nucleation of innovation hubs may be too large.

China

China is one of the most rapidly developing nations in the world — with a huge market and large human resources. It is the third largest economy and the leading manufacturer of a variety of products in the world. Its lower-cost manufacturing operations modulate the price of many manufactured goods throughout the world, which has deterred many countries from investing in manufacturing. Its large trade surplus vis-à-vis the United States attests to the fact that China has become the factory of the world for many manufactured products.

China is different from Japan and Korea in that its political system is totalitarian, albeit with a healthy tolerance for capitalistic business practices. Its political system will enable it to make major investments in capital-intensive businesses that may not yield short-term returns, but enhance its long-term competitiveness. However, its power may be too centralized with limited flexibility. The R&D expenditure is less than those of Japan and Korea, but its rate of increase is about six times that of Japan and three times that of Korea, indicating that China's R&D expenditure will eventually reach parity with Japan and Korea.

Many foreign companies have set up their R&D laboratories (e.g., Microsoft) in China to make use of the well-educated human resources available at still-reasonable costs. Expanding R&D activities in China makes sense not only because of the labour pool, but also because many potential customers for these products are in China.

Despite this rapid advancement, innovation in China seems to be years away (comparable to that of Korea 15 years ago) since it is mainly interested in manufacturing products that have well-established markets. However, the situation could suddenly change if China takes advantage of its large foreign exchange to make massive investments in select areas of technology.

FUTURE PROSPECTS: INNOVATION POLICY IN KOREA

Korea needs to strengthen the innovation process at both the institutional and the individual level. Korea's ability to innovate is impeded by political, organizational and financial factors. Modifying incentives for innovation and strengthening the reward system to allow risk-taking can remove or counteract these impediments. Korea needs to modify its onerous auditing system, which was instituted to make all organizations supported by taxpayers more transparent, but now discourages risk-taking and hampers innovation.

The policies that should be reviewed are as follows:

1. The Korean government should devise fiscal and monetary policies so as to provide financial incentives for risk-taking and innovation.
2. National laboratories should be made more productive by encouraging them to create large systems solutions that satisfy societal and industrial needs.
3. Korea should establish an "Innovation Policy", in addition to its R&D policy.
4. The public sector's R&D resources should be used to solve major problems that can have significant societal and economic impact in the 21st century.
5. The Korean government should entice foreign venture capitalists to Korea for the purpose of promoting innovation and opening up the global market for innovative products.

CONCLUSIONS

1. The three laws of innovation are useful in assessing what each country must do to increase its rates of innovation. Each country should re-examine their innovation policies to be sure that they satisfy these laws.
2. Major industrialized nations of Asia, i.e., China, Japan, Korea and Taiwan, have done well in well-established industries, but they are lacking in producing major innovations, perhaps because they do not have major innovation hubs.
3. To spur economic growth in the 21st century, Korea must foster major innovations through reforms of its education systems, more investment in new ventures, and changes in R&D culture to encourage independent and creative thinking.
4. Asian countries should analyse their *innovation continuum* to identify missing elements. The current economic turmoil should be viewed as an opportunity to take more calculated risks, conduct creative research and reward innovations.
5. All four Asian nations should have policies of providing a home for innovative ideas and people in their country and encouraging immigration of creative people from other nations. At the same time, these nations should deploy policies that will discourage innovators from leaving their country. It must provide a living environment for high quality of life, including strong educational infrastructure and health care.

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