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## Contents

# An Empirical Productivity Analysis of ASEAN Economies in Transition Towards Knowledge- Based Economy

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**Abstract**

Over the past few decades, countries in the Association of South East Asian Nations (ASEAN) have achieved varying levels of economic development. In this paper, the nature and extent of productivity changes in Cobb-Douglas production function components and the growth of the knowledge economy of selected ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore plus South Korea are analyzed over the period 2005 to 2010. Utilising non-parametric Data Envelopment Analysis (DEA) and the Malmquist total factor productivity (TFP) index, individual country's efficiency and productivity changes which took place within this period are estimated. Although there are vast numbers of studies conducted on firm-level and industry-level efficiencies, there is scant literature on inter-country productivity comparisons using the Malmquist productivity index (MPI). The Malmquist TFP index, calculated within the framework of DEA, is broken down into three constituent elements accounting for different sources of productivity growth, namely technological progress, efficiency change, and the effects of economies of scale. Our results indicate that the Philippines and Singapore reported the highest increase in TFP within the referred years, and this growth in productivity is derived from both technical efficiency gains and technological progress. On the other hand, for the knowledge economy model, there is a remarkable growth in TFP for Thailand and Philippines. A comparison with better performing countries helps to identify policies for further improvement in ASEAN member countries.

**Keywords**: Malmquist Productivity Index, Cobb-Douglas, Knowledge Economy, Technical Efficiency, Technological Change, Human Capital, ICT, Productivity Growth, ASEAN

## 1. Introduction

The early 1990s saw a restoration of the neoclassical growth framework used to explain the economic miracle of East Asia with a particular importance on Total Factor Productivity Growth (TFP) (Taylor, 2007; World Bank, 1993; Krugman, 1994; Young, 1994).The findings of many studies, for instance Kim and Lau (1994), Young (1994) and Krugman (1994) stated that the levels of growth experienced by the East Asian economies are the results of high accumulation of both capital and labour with little or no role played by technological progress. In short, growth for many South East Asian countries is input driven rather than productivity driven.

This implies that growth of many of the East Asian economies will cease as soon as diminishing returns set in. Therefore growth is not sustainable in the long run. Under such circumstances, without technical progressand without developing as a knowledge-

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based economy (KBE), the growth potential of these economies will be limited (Bashar, 2012) (see reference for a discussion of the characteristics of a KBE). The advantage of a KBE over a production based (P-Based) economy is that the former is considered an economy where knowledge, creativity and innovation play an ever-increasing and important role in generating and sustaining growth whereas in a P-based economy knowledge plays a less important role in growth. In a P-based economy, growth is driven much more by the accumulation of the factors of production of land, labour and physical capital (Afzal & Lawrey, 2012a, 2012b). The growth of human capital and information and communication technology (ICT) are the essence of the knowledge economy. Thus the motivation for this study is to investigate the current state of conventional total factor productivity growth (TFP) i.e. the Cobb-Douglas production function and knowledge economy growth in selected countries of ASEAN in order to aid in policy formulation. The development of ICT and human capital investment can support the effective use of the technology and innovation. To achieve the above-mentioned objective, we employ the non-parametric frontier method of Data Envelopment Analysis (DEA) to compute the Malmquist Total Factor Productivity (TFP) indexes for a sample of ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore plus South Korea. This technique allows us to decompose the Malmquist TFP index into three components: (a) shifts in production technology, (b) pure changes in technical efficiency, and (c) effects of economies of scale. We calculate the conventional Cobb-Douglas production function and the growth of the knowledge economy by using the Malmquist productivity index to show the current state of the ASEAN economies. The paper comprises five major parts. Following the introduction, Section 2 highlights a brief literature review on East Asian Total Factor Productivity (TFP) growth. Section 3 describes the research framework, sources of data, and methodology. Results and discussion are presented in Section 4. And Section 5 draws conclusions and policy suggestions.

## 2. Literature Review of East Asian TFP Growth

In 1994, Young ranked the Asian countries according to total factor productivity change. He showed in his study that Taiwan, South Korea, Japan and Singapore have higher factor accumulation growth than other South-East Asian countries. However, in 1995, Young revealed that many East Asian economies has significantly lower TFP growth values to those in industrial economies. TFP growth in Singapore, for instance, was estimated to be 0.2% for 1986-90. Young's findings are consistence with studies conducted by Yuan (1986, 1985) and Kim and Lau (1994).

In subsequent application of the growth accounting approach, Taylor (2007) indicated that almost all of Singapore's output growth in 1966-80 could be the reason of increase in the quantities of factor inputs especially labour input rather TFP growth. He added in his book Singapore during that time period were highly dependent on conventional factors of production to generate higher economic growth rate.

Kim and Lau (1994) presented several reasons for the lack of measured growth in productivity efficiency over time for the newly industrialized countries (NICs) in late 1950s and 60s. Firstly, there is the possibility of scale effects which is difficult to measure with conventional econometric growth accounting approach. Second, research and development was relatively unimportant in the East Asian NICs due to the lack of investment in public R&D expenditure as well as the scarcity of indigenous technological improvements. Thirdly, the rapid capital deepening in the NICs is not knowledge-intensive nor ICT driven. Finally, poor natural and specially human resource endowment may have reverse the potential gains in technical progress.

In our study we initially use the conventional Total Factor Productivity formula before using non-parametric test to see the consistency of TFP growth between parametric vs. non-parametric test. We briefly highlight the results here.

The Cobb-Douglas production function can be expressed as

$$Y = A * L^{a} * K^{(1-a)} \quad (1)$$

This expression is referred to as a measure of total factor productivity; that is, the scalar A has an economic meaning. The denominator is a geometric-weighted average of the inputs used to produce real output. Thus, A can be interpreted as real output per unit of input. This is a better measure of productivity when compared to Y/L, Y/K, or Y/land which are measures of partial productivity. Partial productivity measures do not take into account the possibility of differing amounts of other inputs used in production which might account for the greater or lesser productivity of a single input. One of the known methods of model for parametric estimation is the Ordinary Least Squares (OLS) method (Taylor, 2007). Estimation and calculation by Cobb-Douglas production function has been done in this part by collected data of real gross domestic product (GDP), gross fixed capital formation (GFCF) as a percentage of GDP represents capital (K), total labor force (15-64 years) as L, and secondary school enrolment as a percentage of total school age population represents the human resource endowments during 2005-2010. The functional form looks like,

$$LGDP= \alpha+\beta_{1LnL}+\beta_{2LnK}+\beta 3_{LnSe}+\mu \quad (2)$$

and we are interested in the intercept α which represent the scalar A. Taking each α value for every country, we take the antilog and finds the value of scalar A. For each country we run the same regression with same set of variables and time period. Our results exhibits that the Philippines having 3.8 intercept value rank the top most position compare to other six economies. South Korea and Thailand having 3.46 and 3.09 intercept values ranked second and third position respectively. On other hand Singapore and Malaysia scores 3.01 and 2.05 respectively during the time span. However, Indonesia having 1.9 intercept value is a less successful countries in ASEAN during our referred years while converting input to output factors of production. We are expecting the similar kind of ranking when we apply DEA MPI method in Cobb-Douglas production function analysis. As we see it is difficult to capture scale effect through the parametric regression analysis, we apply a non-parametric DEA MPI test to analyze the TFP growth in ASEAN. The brief review of advantages of using DEA MPI method is given in Table 1A in Appendix 1.

## 3. Research Framework

In this study we first calculate the conventional Cobb-Douglas production function using real gross domestic product (GDP), gross fixed capital formation (GFCF) as a percentage of GDP, total labour force (15-64 years), and secondary school enrolment as a percentage of total school age population as inputs. The output for the DEA Malmquist Index analysis comprises real GDP. Data are collected from the World Competitiveness Yearbook 2010 (WCY-2010), World Development Indicators 2010 (WDI-2010) and ASEAN statistical yearbooks.

To measure knowledge economy productivity, we consider education expenditure and the school enrolment ratio as an input variable and computer users per thousand populations as the output variable. OECD (1996), WBI (1999), Derek, Chen and Dahlman (2004) emphasized that education and skilled workers are key to efficient knowledge dissemination which tends to increase productivity when shared by information and communication technology (ICT) infrastructure. ICT infrastructure refers to the accessibility of computers, internet users, mobile phone users etc. The sample period for this study spans from 2005-2010, a total of 6 years. Subsequently this study measures both Cobb-Douglas and knowledge economy productivity using the Malmquist index for selected ASEAN countries.

### *3.1 DEA and the Malmquist Productivity Index (MPI) Methodology*

DEA was originally developed by Charnes, Cooper and Rhodes (1978). It involves the use of linear programming methods to construct a non-parametric frontier approach over the data, so as to be able to calculate efficiencies relative to this frontier. DEA does not require a functional form like parametric techniques. Instead, DEA uses input and output data to compute a technically efficient production frontier, i.e. a surface formed by the most efficient units. The best units receive an efficiency score of one (or more practically, 100 per cent), while the other units receive scores below one, depending upon their position in comparison with the most efficient units.

In this paper, Data Envelopment Analysis (DEA) is utilized to compute the distance functions of the Malmquist Productivity Index (MPI). All of the Malmquist indices of each country's data were derived using the program DEAP Version 2.1 developed by Coelli (1996). This software has been written to conduct data envelopment analysis for the purpose of calculating efficiencies in production for both cross-section and time series analysis. Malmquist productivity analysis uses panel data to calculate indices of total factor productivity change, technological change, technical efficiency change, pure technical efficiency change and scale efficiency change. Fare, Grosskopf and Lovell (1994) have provided a detailed discussion of this decomposition. Our main focus is to explain the methodology in a non-technical way for easier understanding of the method. The functional form of the DEA MPI explanation is given in Appendix 1 at the end of this article.

Malmquist indexes have a number of desirable features. They do not require input prices or output prices in their construction, and are also unit independent. They are easy to compute, as demonstrated by Färe et al. (1994). The MPI is capable of accommodating multiple inputs and outputs without worrying about how to aggregate them. An attractive feature of the Malmquist productivity index is that it decomposes into two components – technical efficiency change and technical change (Färe et al., 1994). Technical efficiency refers to the ability to use a minimal amount of input to produce a given level of output. Over time, the level of output an industry is capable of producing will increase due to technological changes that affect the ability to optimally combine inputs and outputs. Thus for any organization in an industry, productivity improvements over time may be either technical efficiency improvements (catching up with their own frontier) or technological improvements (because the frontier is shifting up over time), or both. The value of this decomposition is that it provides insight into the sources of productivity change.

The original MPI assumes constant returns to scale for the production process. As a result, the original MPI typically overestimates productivity change if the production process displays decreasing returns to scale or underestimates it for increasing returns to scale. To cope with the issue of variable returns to scale, Fare et al. (1994) recommended the use of a generalized MPI that includes an additional component, called scale index, to represent the effect of economies of scale on productivity. We also include such a scale factor in our analysis. Scale efficiency refers to the extent to which an organization can take advantage of returns to scale by altering its size towards optimal scale.

One way to measure a change in productivity is to see how much more output has been produced, using a given input level and the present state of technology, relative to what could be produced under a given reference technology using the same input level. An alternative is to measure the change in productivity by examining the reduction in input use that is feasible given the need to produce a given level of output under a reference technology. These two approaches are referred to as the output-oriented and input-oriented measures of change in productivity, respectively (Coelli, 1996). This study concentrates on the output-oriented Malmquist productivity index.

The Malmquist DEA approach derives an efficiency measure for one year relative to the prior year, while allowing the efficiency frontier to shift. A value greater than unity indicates positive total factor productivity growth whereas a value of less than unity indicates productivity decline. The next section presents the results and discussion.

## 4. Empirical Results

Table 1 presents the geometric means of the MPI for each country and the breakdown of its

**Table 1** Geometric means of MPI and its components (Cobb-Douglas), 2005-2010

| DMU | effch | techch | pech | sech | tfpch |
|---|---|---|---|---|---|
| Indonesia | 1.000 | 1.073 | 1.000 | 1.000 | 1.073 |
| Malaysia | 1.068 | 1.060 | 1.000 | 1.068 | 1.133 |
| Philippines | 1.084 | 1.059 | 1.000 | 1.084 | 1.148 |
| Singapore | 1.076 | 1.065 | 0.985 | 1.092 | 1.146 |
| Thailand | 1.037 | 1.057 | 1.046 | 0.991 | 1.096 |
| South Korea | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| **Mean** | **1.044** | **1.052** | **1.005** | **1.038** | **1.098** |

Note: Effch – Technical efficiency change, Techch – Technological change, Pech – Pure technical efficiency change, Sech – Scale efficiency change, Tfpch – Total Factor Productivity (TFP) change, DMU – Decision making unit

MPI into five components: technical change (Effch), technological change (Techch), pure efficiency change (Pech), scale change (Sech) and total factor productivity change (Tfpch). In Table 1 we use the components of the Cobb-Douglas production function, namely population of 15-64 age as the labour force, gross capital formation as a percentage of GDP as capital, and secondary school enrolment as a percentage of the total secondary school age population as human capital as input variables and real GDP as the output variable for the MPI model.

If the changes in the total factor productivity (TFPCH) index is greater than one (TFPCH > 1), it shows that there is an increase in TFP. If the TFPCH is lower than one (TFPCH < 1), it means that there is a decrease in TFP. As mentioned previously, there are two components of TFP; these are changes in technical efficiency (EFFCH) and changes in technology (TECHCH). If these two indices are higher than one, it means that there are improvements in both technical efficiency and technology. If they are lower than one, it means that there are decline in both technical efficiency and technology.

We can divide the EFFCH index into two sub-index called changes in pure efficiency (PECH) and changes in scale efficiency (SECH). The SECH index shows the extent tp which production is in an appropriate scale. Decomposition of the Malmquist TFP index is useful to determine the sources of the changes in TFP (Ramanathan, 2003).

As evident from Table 1 (the model with Cobb-Douglas components), South Korea is the reference country for total factor productivity with a score of 1.0. In other words, South Korea is the optimally efficient country on the production frontier. The Philippines and Singapore exhibit average annual positive increases in total factor productivity of 14.8% and 14.6% per annum respectively over the sample period. For Philippines, this increase in TFP was composed of an 8.4% technical efficiency gain and 5.9% due to technological progress. For this country, there has been no change in pure technical efficiency, so the technical efficiency change was solely the product of scale efficiency expansion, which was 14.8%. A similar observation is recorded for Singapore which also exhibited a productivity gain. On the contrary, Malaysia, Thailand and Indonesia recorded a lower value in the TFP compared to the Philippines and Singapore over the sample period. All countries exhibit a positive improvement in technical and technological efficiency. Indonesia, however, appears to be the least successful country and South Korea shows no change in TFP of the MPI. By allowing for constant returns to scale it can be shown that technical efficiency grew in most of the ASEAN countries.

The results presented in Table 2 include knowledge economy growth considering education expenditure and secondary school enrolment as a percentage of the total secondary school age population as the input variable and computer users per 1000 populations as the output variable in computing the MPI. These variables reflect the knowledge dissemination dimension of a KBE (see Afzal and Lawrey, 2012b).

We can see in Table 2 (model with knowledge

**Table 2** Geometric means of MPI and its components (Knowledge economy), 2005-2010

| DMU | effch | techch | pech | sech | tfpch |
|---|---|---|---|---|---|
| Indonesia | 1.055 | 1.042 | 1.000 | 1.055 | 1.099 |
| Malaysia | 1.025 | 1.063 | 1.000 | 1.025 | 1.089 |
| Philippines | 1.025 | 1.063 | 1.000 | 1.066 | 1.133 |
| Singapore | 1.000 | 1.052 | 1.000 | 1.000 | 1.052 |
| Thailand | 1.069 | 1.063 | 1.099 | 0.973 | 1.136 |
| South Korea | 0.999 | 1.061 | 0.998 | 1.001 | 1.060 |
| **Mean** | **1.035** | **1.057** | **1.015** | **1.019** | **1.094** |

Note: Effch – Technical efficiency change, Techch – Technological change, Pech – Pure technical efficiency change, Sech – Scale efficiency change, Tfpch – Total Factor Productivity (TFP) change, DMU – Decision making unit

economy components) that the annual average value of EFFCH index is 1.035. This means that there is an improvement in technical efficiency in general. There is no decrease in the components of EFFCH. The mean TECHCH index is increased by 5.7%. The increase in TECHCH causes the increase in TFP. This implies that ICT and human capital have improved in all ASEAN countries.

The reference country for technical efficiency change (EFFCH) is Singapore with a score of 1.000. The value of the EFFCH indexes for Indonesia, Malaysia, the Philippines and Thailand are greater than one. This means that these countries have a higher catching-up effect to reach the optimal production border/frontier. In other words, these countries are successful in catching up with the best production border that is determined by the reference country (Singapore). The most successful country for catch up is Thailand (6.9%). However, South Korea has EFFCH levels lower than 1. This means that there is no catching up effect in South Korea. Singapore is the reference country which means it is stable, on the best production frontier. In other words, annual average technical efficiency level of Singapore is not changed.

According to the technological change index (TECHCH), Malaysia, the Philippines and Thailand obtained the highest technological improvement in the period 2005-2010. South Korea, Singapore and Indonesia follow these countries respectively. In that period all countries experienced technological improvement and the annual average TECHCH index is measured at 1.057 with the TFPCH index measured at 1.094 for all countries. As the TECHCH index is greater than 1, it shows that the annual average of the production frontier has been shifted up by technological improvement. When we look at the TFP of countries, we can see that Thailand and the Philippines have the highest increase in annual average TFP. This implies that both the countries have improved their ICT and human resources development significantly within the reference period. The next section presents the conclusion and policy implications.

## 5. Conclusion and Policy Implication

This paper seeks to explore whether the growth in productivity in ASEAN is attributed to either technical efficiency change or technological change or both, and how ASEAN countries stand in human capital and ICT development. To achieve the above-mentioned objective, we employ the non-parametric frontier method of data envelopment analysis (DEA) to compute the Malmquist Total Factor Productivity (TFP) indexes for a sample of ASEAN countries, namely, Malaysia, Indonesia, Philippines, Thailand, Singapore plus South Korea. The technique used allows us to further decompose the Malmquist TFP index into three components: (a) shifts in production technology, (b) pure changes in technical efficiency, and (c) effects of economies of scale. By allowing for constant returns to scale it can be shown that technical efficiency grew in all selected ASEAN countries. The Philippines claimed the greatest progress in technical efficiency of 8.4% per annum followed by Singapore with increased efficiency of 7.6% per annum There is a positive technological change for all countries using Cobb-Douglas production function components. The highest total factor productivity increase occurred in the Philippines. Singapore and South Korea were identified as the best performers or reference countries.

When education expenditure, secondary school enrolment and computer users per thousand population are used as input variables for knowledge economy growth in the second model, the results indicate that Thailand and the Philippines experienced significant improvement in knowledge TFP growth. Other countries exhibit positive improvements of the TFP but lower than the Philippines in knowledge dissemination.

There are two ways to improve the TFP of knowledge economy growth. First of all, if the selected countries solve the inefficiency problem by reallocation of resources, they can improve their TFP of the ICT sector and become more competitive. Secondly, the technological improvement in these countries creates an expectation about increasing TFP of ICT and human resource development. If there is a sustainable technological improvement by innovation, it will cause a sustainable increase in the TFP of ICT sector and as a result it will cause a sustainable increase in competitiveness. Comparison with better-performing countries helps to identify policies for further improvement. Furthermore, identifying which country lags behind with respect to ICT and human resources adoption provides a benchmark to enhance the cooperation among the ASEAN member countries and other Asian countries in developing the knowledge-based economy for the region as a whole. Human capital is considered to be the fuel to drive the knowledge economy that is based on knowledge assets which is a combination of human capital and ICT. The major weakness of DEA, MPI method is to detect outliers from the sample. In future bootstrapping DEA MPI analysis will certainly improve the quality of the research. We believe the discussion and method presents in this paper will contribute in existing literature of productivity analysis.

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## Appendix 1

*Functional definition of DEA MPI as follows:*

$$M^{t+1}(x^{t+1},y^{t+1},x^t,y^t) = \left[\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}\right]^{1/2} \quad (3)$$

Where $D^t$ is a distance function measuring the efficiency of conversion of inputs $x^t$ to outputs $y^t$ in the period t. As we know, DEA efficiency is considered a distance measure in the literature as it reflects the efficiency of input output conversion of DMUs. In fact if there is a change in technology in the following year which is (t+1), then,

$D^{t+1}(x^t, y^t)$ = efficiency of altering input in period t to output in period t $\neq D^t(x^t, y^t)$.

Hence we can say technically Malmquist Productivity Index (MPI) is a geometric average of the efficiency and technological changes in the two referenced periods and it is thus can be written as:

$$M^{t+1}(x^{t+1},y^{t+1},x^t,y^t) = \left[\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\right]\left[\frac{D^t(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})}\frac{D^t(x^t,y^t)}{D^{t+1}(x^t,y^t)}\right]^{1/2} \quad (4)$$

M = ET

Where E is the technical efficiency change and T is

**Table A1** The Comparison between econometric and DEA MPI productivity analysis methods

| | Econometric | DEA MPI |
|---|---|---|
| Characteristic | Parametric method | Non- Parametric method |
| Efficiency measurement | Technical change and TFP change in terms of significant variables. Does not reveal scale, technological changes in the productivity. | Technical efficiency, scale elasticity, scale efficiency, allocative efficiencies, technical change and TFP change, Technological efficiencies changes |
| Strengths | 1. It does not assume that all firms are efficient in advance<br>2. Regression analysis makes accommodation for statistical noise such as random variables of weather, luck, machine breakdown and other events beyond the control of firms and measure error.<br>3. It is capable to hypothesis test<br>4. It estimates based on average not as best practice frontiers<br>5. Econometric method are not unit invariant. | 1. It does not assume that all firms are efficient in advance.<br>2. It could handle with efficiency measurement of multiple outputs but weak in measuring noise in the analysis.<br>3. It does not need to price information available.<br>4. It does not need to assume function type and distribution type<br>5. While sample size is small, it is compared with relative efficiency<br>6. Both the CCR and BCC models have nature of unit invariance which leads MPI unit invariant too. |
| Weakness | 1. It needs to assume functional form and distribution type in advance<br>2. It needs enough samples to avoid lack of degree freedom<br>3. The assumed distribution type is sensitive to assessing efficiency scores | 1. It does not make accommodation for statistical noise such as measurement error<br>2. It is not capable to hypothesis test.<br>3. When the newly added DMU is an outlier, it could affect the efficiency measurement. |
| Application | It has applied to measure productivity performance of organizations in terms of single output or dependent variable. Econometric regression or growth accounting method hardly can incorporate more than one dependent variable. | It has applied to assess productivity performance of non-profit/profit organizations or branches of firm with multiple input and output which gives MPI superiority over regression analysis. |

Source: Coelli et. al. (1996)

[i] The Cobb-Douglas production function can be expressed as $Y = A * L^a * K^{(1-a)}$
where: Y is real output
A is a scalar (measure of change due to technological improvement)
L is a measure of the flow of labour input
K is a measure of the flow of capital input

the technology change. E measures the change in the CRS technical efficiency of period t+1 over that in t. If E is greater than 1, we assume there is an increase in the technical efficiency. However, T represents the average technological change over the two referred periods.

*Advantages of using MPI*

Usually for econometric analysis researchers tends to use growth accounting method where a Cobb-Douglas production function regress to find the productivity changes across the nations. However, due to its limitation, we apply DEA MPI method which can capture a robust characteristics of productivity changes. In Table 1 our study reveals the distinction between econometric and DEA MPI methods.

# Enabling Factors and Performance of S&T Based Societal Projects: An Indian Case Study

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**Abstract**

The aim of the present study was to analyze various intricacies and complexities of the S&T based societal projects, and to identify the enabling factors of such projects. An analysis was carried out to assess the benefits to the community of these funded projects by evaluating the impact of technologies on the project outcomes, and on the target beneficiaries. For the present analysis, the societal projects supported during a five-year period were considered. The analysis covered 491 projects sponsored to 306 organizations in different parts of the country, at a total cost of about INR 360 million. The analysis shows that such projects not only bring tangible benefits to the target beneficiaries and the area but also empower them in deriving benefits of the technological advancements.

The analysis was conducted covering two major aspects- outcome of the projects and identification of the enabling factors which governed the design, management and performance of the projects. The second part of analysis focused on the identification of a set of enabling factors comprising input and output variables to quantify the design and management aspects as well as performance of projects in terms of productive outcomes, extent of sustainability and potential for replicability.

The analysis also presents a methodology to the funding agencies as well as to the planners in designing S&T based societal programmes keeping in view the critical enabling factors so that the returns from the investments are optimally utilized and to make these projects successful in terms of ensuring their replicability and utilisation in various sectors of sustainable development. Based on the analysis, the paper suggests that a package of strategies can be adopted for the projects to be more focussed, productive and sustainable over the time, particularly for development of sustainable micro-enterprises, and for potential replication and scaling up.

**Keywords**: Science & Technology, Societal Project, Innovation, Rural Development, Performance Indicators, Livelihood.

## 1. Introduction

An important role of science and technology in a developing country like India is to facilitate the community with the tools and techniques to address the realities of life, e.g. poverty, unemployment, drudgery in daily chores and livelihood works, lack of essential amenities. Technology is considered to be among the greatest enablers for improved quality of life. Brewer et al. (2005) presented the benefits of a variety of ICT applications in developing regions, including in India. Through S&T interventions, a lot of employment generation is possible in the rural sector, leading to value addition in the rural living (Haque, 1991). Kumar and Jain (2002) analyzed the inherent uncertainties and associated risks in the development

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and commercialization of new technologies for societal benefits, and presented policy perspectives for encouraging new technologies in an enabling environment.

India now has few successful models of community based development works in rural areas (even involving private sectors), covering the activities in areas of healthcare, education and literacy, water, sanitation, environment, livelihood skills. Use of ICT in irrigation and water distribution, post-harvest technologies for processing and adding value to the produces, cold storage and cold-chains for short-term storage and transportation to market, appropriate energy systems at affordable costs, etc. are some examples of needed technology applications in rural areas. Societal projects operating in India basically aim at providing economic and environmental benefits to the society, for example through application of technology in agricultural, horticultural, health, water & energy sectors, thereby integrating science and technology with the village economy.

Technology based societal projects have generally performed well and had good success rate in the country (Goyal & Dixit, 2008; Raina, 2008). These projects are largely supported by Ministry of Science & Technology, Ministry of New & Renewable Energy, Ministry of Rural Development, and in the non-government sector by agencies like DFID, UNDP, UNESCO, UNEP, World Bank, Asia Development Bank, NABARD (RIF), and SIDBI. In such projects, the problem to be solved and the solution offered (including technology) are based on the local conditions, needs, demands and availability of resources, and are derived from the field through participatory approaches involving local community (Dasgupta et al., 2004). Rural Innovation Policy Working Group (RIPWiG) of the UNU-INTECH, as part of a DFID funded research project "New insights into promoting rural innovation: learning from civil society organizations", reviewed two science and technology-based rural development schemes of the Government of India. The Group reported that the S&T Applications for Rural Development (STARD) scheme of the Department of Science & Technology, which forms part of the schemes covered under the present paper, facilitated strengthening and capacity building of the supported NGOs in developing into centres of excellence (INTECH, 2005). Evaluation of such R&D-based projects based on the outcomes and analyzing their performance indicators is critical to make them more effective as well as productive (Hong et al., 2012). This study attempts to identify a set of enabling factors which tend to make the project-based interventions more productive in terms of the outcomes, techno-economic viability and long-term sustainability and replicability.

## 2. Research Framework

Through societal projects, the Department of Science and Technology (DST) has been performing the role of a facilitator in creating a strong interface between science and the country's poor, particularly in the rural areas. The programme has helped a large number of grassroot organisations, beneficiary groups and development institutions in understanding the S&T needs of the poor and supported a large variety of S&T-based development projects (GoI, 1997).

All the supported projects are evaluated annually through a peer review mechanism comprising of subject experts and departmental officers. At these 'annual review meetings', the project investigators make presentation of the progress achieved against the approved objectives during the reported period. Continuation of the project (and release of funds) is subject to the satisfactory performance of these projects.

Further analysis was carried out on a set of completed projects to assess the benefits to the community of these funded projects by evaluating the impact of technologies on the project outcomes, and on the target beneficiaries. The analysis was conducted covering two major aspects; outcome of the projects and identification of the enabling factors which governed the design, performance and management of the projects.

The second part of analysis focused on the identification of a set of enabling factors comprising input and output variables to quantify the design and management aspects as well as performance of projects in terms of productive outcomes, extent of sustainability and potential for replicability. The information required for analysis was also supplemented through field visits to the project sites. The analysis gave useful insight into the intricacies and complexities of the S&T based societal projects, which could be used for fine tuning the future direction for such projects.

## 3. Case Study

In this study, the societal projects sponsored by DST during a five-year period (1998-99 to 2002-2003) were considered. The analysis covered 491 projects sponsored to 306 organizations in different parts of the country, at a total cost of about INR 360 million. The main type of activities undertaken during execution of these societal projects included (1) technology development, (2) technology development and transfer, (3) technology transfer and training, and (4) training programmes. The first category of projects, i.e. 'technology development' includes technology adaptation with upscaling/downscaling and modifications suiting the local conditions. For the present analysis, a representative sample of 103 projects was used to perform a correlation analysis to derive the inferences. The sample projects selected were those which demonstrated good results during execution and performed well during various evaluations.

### *3.1 Projects Coverage*

#### *3.1.1 Target Beneficiaries*

81% of the projects were undertaken in rural areas, 11% in urban and 8% covering both. The analysis indicates that 25% of the projects were addressed to the SC/ST population (including scavengers and collectors of non-timber forest produces) and 24% to the farmers, which included orchid farmers, poultry farmers and fishermen. For about 12% of the projects, the target groups were artisans and crafts-persons, about 30% of the interventions were designed to reach out to women and 7% to youth. Also, 2% of the projects were found to be focused on the handicapped, rickshaw-pullers, disaster management personnel, Gharat (watermill) owners and slum dwellers.

The finding also suggests that 64% of the projects addressed target groups of less than 100 beneficiaries, indirectly indicating their relatively smaller geographical coverage. For 17% of the projects, the size of target groups was 100-200. Another 19% of them were designed to reach out to more than 200 beneficiaries.

#### *3.1.2 Projects Distribution*

During the reported period, 44% of the societal projects sponsored by the DST pertained to transfer of available technologies at the grassroot level. 17% of these were focused on technology development and transfer (including skill building among the target beneficiaries). Significantly, 15% of the projects led to development of improved technologies to meet the needs of socio-economic development at the grassroots. The percentage of projects that were focused primarily on imparting training for skill formation among the beneficiaries was 12%. Another 12% of them pertained to awareness building, publications, research studies, scholarship scheme, workshops, website development, etc.

About 52% of the total funding pertained to projects dedicated to technology transfer and training. 16% of this funding was provided for technology development and transfer and 13% for conducting R&D for technology development. The projects with the mandate of providing training accounted for about 10% of the total funding and 10% projects belonged to the other categories.

#### *3.1.3 Project Dispersal Ratio and Funding Dispersal Ratio*

This indicator was used to ascertain the dispersal of projects among the participating organizations. It is defined as:

$$Funding\ Dispersal\ Ratio = \frac{\text{accounting for 50\% of projects}}{Total\ number\ of\ organizations} \quad (1)$$

It was found that 72 organizations accounted for 50% of the projects sponsored during the reported period. Therefore, *Project dispersal ratio*= 72/306 =23.5. This shows that the projects' sponsorship is not very widely distributed among the participating organizations, and a group of select organizations tends to dominate in project funding.

To ascertain the dispersal of project funding among the participating organizations Funding Dispersal Ratio was used, which is defined as:

$$Funding\ Dispersal\ Ratio = \frac{\begin{array}{c}Number\ of\ organizations\\ \text{accounting for 50\% of total funding}\end{array}}{Total\ number\ of\ organizations} \quad (2)$$

It was seen that 47 organizations accounted for 50% of the project funding during the reported period. Therefore, *funding dispersal ratio*= 47/309=15.2. Since this ratio is less than the project dispersal ratio, it implies that project sponsorship in terms of funding was even far less distributed among the organizations.

### *3.1.4 Type of Organizations*

During the study period, 306 organizations received project support under the Programme. 74% of the projects were undertaken by S&T based voluntary agencies and 17% by educational institutions (universities/college/medical colleges/engineering colleges/IITs). The national labs accounted for 5% of the projects, and the private R&D centres and State S&T councils accounted for 2% each. Thus, S&T based voluntary agencies accounted for 82% of the total funding during the five-year period with a share of education institutions being 11% and that of national labs/institutions about 4%. The funding support to the State S&T councils and organizations in other category was very small.

### *3.1.5 S&T Activities*

Since the programme mainly focuses on the rural settings, the farm and off-farm activities, categorized under various operational S&T fields, dominated in the supported projects (Table 1). The highest number of projects pertained to agriculture and related areas (21%), followed by forestry (14%), artisanal and crafts technologies (10%), animal husbandry (6%), health and hygiene (6%), integrated rural development (6%) and water resource management (5%). In about 5% of projects, Technology Parks were set up for promotion of livelihood opportunities based on S&T based interventions.

### *3.1.6 Source of Technology*

In 51% of the projects, the technologies/know-how employed was developed solely in-house by the project implementing organizations, while in 7% this was worked out in consultation with outside experts. 27% of the projects were based on transfer of technology from a technology generator (S&T institution/development agency/voluntary agency/individual innovator). In case of 15% of interventions, the technology was developed by carrying out modifications in the existing practices of the beneficiaries.

### *3.1.7 Sustainability and Replicability*

From the study, the sustainability of the project-based interventions at the grassroots was found to be low as only 21% of the projects seemed to have developed clear-cut follow-up mechanisms after their completion. Only 4% of the projects investigations reported replication of their work in other locations and dissemination of their project model among other agencies. This indicates a rather self-limiting and isolating nature of most of the projects. This observation is further supported by very low coverage (2%) of the project investigations in media.

**Table 1** Projects according to operational S&T field

| S&T Field | % of projects |
|---|---|
| Agriculture and Related Areas | 21 |
| Forestry and Related Areas | 14 |
| Artisanal and Crafts Technologies | 10 |
| Integrated Rural Development | 6 |
| Animal Husbandry | 6 |
| Health and Hygiene | 6 |
| Rural Technology Parks (including Women Technology Parks) | 5 |
| Water Resources Management | 5 |
| Information and Communication Technologies | 4 |
| Fisheries | 4 |
| Construction Technologies | 3 |
| Waste Management | 3 |
| Engineering Tools and Equipment | 3 |
| Energy Sources | 2 |
| Food Processing | 2 |
| Watershed Development | 2 |
| Others (e.g. rehabilitation technologies, environment technologies, transport technologies, disaster management) | 4 |

### *3.2 Project Outcomes*

The societal projects' basic intent is to enable the local community achieve sustainable livelihoods by building their own technical and organizational capacities, achieving technology choices, and adopting and improving technologies. In this process, technologies are generated, technical facilities are created, livelihood opportunities are improved, environmental benefits are achieved, and extra-mural links are established. Some of these outcomes are discussed next.

#### *3.2.1 Creation of Technical Facilities*

In about 39% of the projects, technical facilities were set up in order to facilitate transfer of technology and imparting on-the-job training to the beneficiaries. Some of the facilities established include: herbal garden, nursery, rain water harvesting system, natural dye processing unit, oil-extraction unit, pottery kiln, low-cost house models, weaving units using improved handloom, hand-made paper making unit, water quality analyzer, bio-gas plant, vermi-composing unit, improved fishing boat, grain storage unit, sewage treatment plant (Figure 1).

#### *3.2.2 Generation of Technologies*

During the period under study, the total number of technology generated under the project-sponsorship mode was 144. This corresponds, on an average, to 29 technology generated in a year. Since the number of project implementing organizations was 306, the average number of technologies generated per organization was 1 technology every 2 organizations. Also, the average number of technologies generated per project was 1 technology every 3 projects.

Table 2 provides the distribution of these technologies among the eight main S&T fields. The highest number (20%) of technologies pertained to agriculture, followed by artisan and crafts technologies (13%) and water management technologies (11%). Animal husbandry and fisheries constituted 9% of the technologies developed under project sponsorship, energy sources 8%, weaving technologies, medicinal

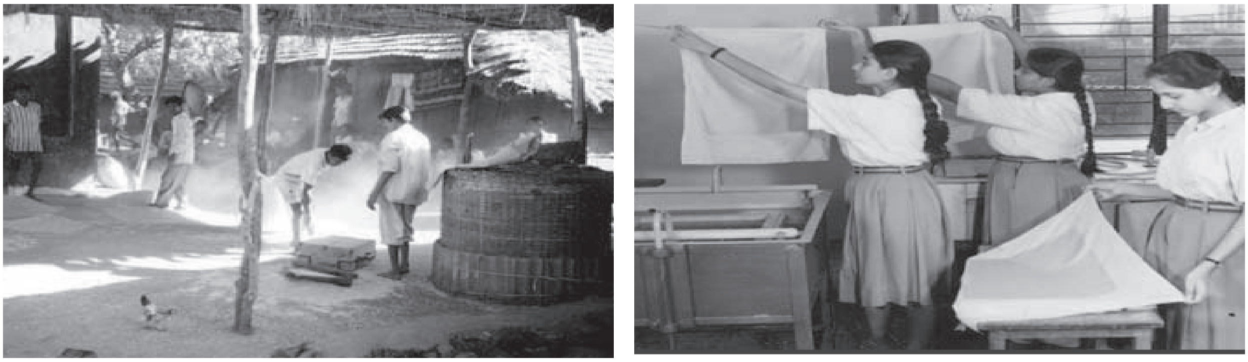

**Figure 1** Grain storage bank (left) and hand-made paper recycling unit (right)

**Table 2** Technologies developed in various S&T fields

| S&T field | Number of technologies | Percentage |
|---|---|---|
| Agriculture | 29 | 20 |
| Artisan & Crafts | 18 | 14 |
| Water Sources | 16 | 11 |
| Animal husbandry/ fisheries | 13 | 9 |
| Energy Sources | 12 | 8 |
| Weaving | 9 | 6 |
| Medicinal Plants | 9 | 6 |
| Biofertilizers | 9 | 6 |
| Construction | 9 | 6 |
| Health and sanitation | 5 | 4 |
| Natural dyes | 5 | 4 |
| Oil Extraction | 4 | 3 |
| Hand-made paper | 2 | 1 |
| Rubber technologies | 2 | 1 |
| Environment technologies | 2 | 1 |
| Total | 144 | 100 |

plants, bio-fertilizers/bio-pesticides and construction technologies 6% each. The technologies pertaining to the other sectors are health and sanitation (4%), natural dyes (4%), oil extraction technologies (3%), hand-paper making (1%), rubber technologies (1%) and environment (1%) (Figure 2-4).

*3.2.3 Economic Outcome and Employment Generation*

It was observed from the available data that 43% of the projects sponsored during reported period led to creation of employment/ income generation opportunities for the target beneficiaries. While only 20% of the projects led to development of sustainable business models such as production and marketing groups/cooperatives/paani-bijali panchyats (water-electricity local governments)/individual micro-enterprises (Figure 5).

Also, it was found that the project sponsorship involved 441 PIs and 279 Co-PIs (excluding repetition of those with more than one project). The total project-based employment generation during the five-year period was found to be 1606 indicating that the Programme supported, on an average, project-based employment to 300 persons in a year.

**Figure 2** System of rice intensification (left) and mushroom cultivation (right)

**Figure 3** Fish aggregation device (left) and artisan technology (right)

**Figure 4** Ethanol-based lantern (left) and biomass gasifier (right)

*3.2.4 Social Outcome*

The social outcomes considered relevant for the Programme are (i) better access to energy sources, (ii) better access to water sources, (iii) better health and nutrition, (iv) betterment of women, (v) services to children, (vi) protection of environment, (vii) reduction in drudgery, and (viii) better living conditions. In this analysis, 'protection of environment' and 'betterment of women' emerged as the foremost social impact areas promoted by 27% of the projects in each case. This seems to indicate that eco-friendly sustainable development and socio-economic upliftment of women through S&T interventions are built strongly in the

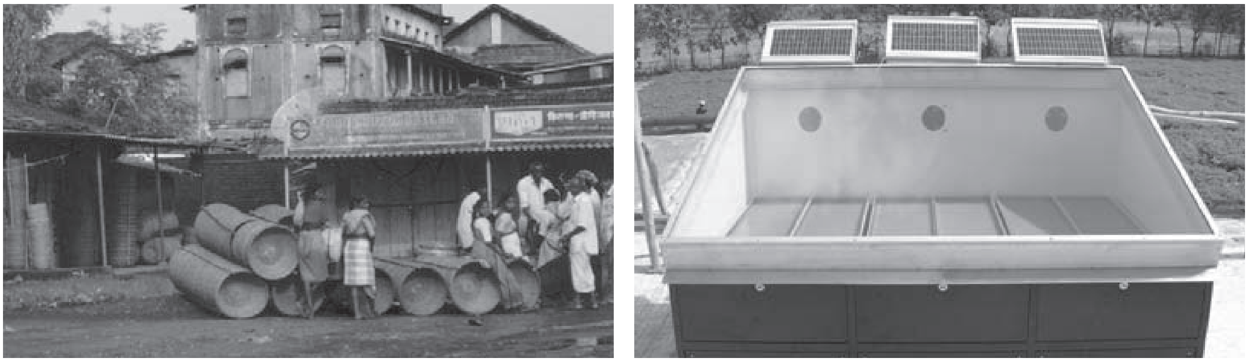

**Figure 5** Enterprises based on bamboo baskets (left) and solar drier (right)

project sponsorship. 16% of the investigations led to betterment of health and nutrition status of the beneficiaries, while 14% created better access to water facilities and 12% led to better living conditions. The number of projects leading to reduction in drudgery (7%), better access to energy sources (6%) and providing services to children (5%) were relatively far less.

*3.2.5 Setting Up of Beneficiary Organizations*

For successful implementation of these projects, an effective strategy is to involve the local community in various operations of the project. Establishment of local beneficiary organizations, such as self-help groups, women's cooperatives, village development committees, saving and credit groups, farmers' groups, watershed committees, forest protection groups, youth clubs, women cells, eco clubs and water cooperatives, has demonstrated its utility in success of these projects. In case of 28% of completed projects, beneficiary organizations were set up. The highest number of beneficiary organizations (40%) was set up in tribal areas.

*3.2.6 Extra-mural Links*

During the period under study, several project implementing organizations established links with S&T institutions, local development bodies, voluntary organizations, industry for creation of technical facilities, testing and fabrication, and market for procurement of material/tools/equipment and for sale of produce (Figure 6). 57% of the projects links were established with the S&T institutions. In 34% of the projects, the projects teams generated the support of the local bodies (Panchayats/village development committees/block development office), while the expertise of the local NGOs were made use of in 27% projects. The links with local industry were set up in 23% of the projects, but the links with market were reported only in about 10% of the projects.

Also, as seen in Table 3, the project implementing organizations availed the expertise of as many as 505 S&T institutions. This corresponds, on an average, to setting up of one linked organization per project, and 100 such links per year.

Among the type of these institutions, the largest links were set up by the implementing organizations with the research institutions (including national labs),

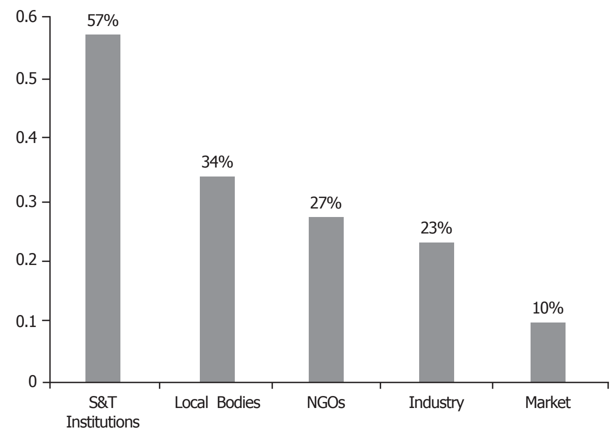


**Figure 6** Extra-mural links according to type of organization

which constituted 53% of the total number of links established. This group of institutions were followed by universities/colleges (18%) and State government agencies (16%).

The links with engineering colleges constituted 6% and those with medical institutions 4%. Significantly, 2% of the extra-mural links were set up with international organizations including the UNDP, the Asia Pacific Centre for Technology Transfer and the World Bank.

*3.2.7 Publications/ Patent Filed*

During the study period, 17% of the projects led to various types of publications (booklets/ manuals/training material/research papers), which are considered important for preservation of knowledge generated, and for wider dissemination among scientists, project implementing organizations and young researchers. The number of research papers generated during the five-year period was 29, and the average number of papers per project was 6 papers every 100 projects. Also, the project sponsorship led to the filing of three patents. It is observed that the intellectual property (e.g. publications and patents) generated in the projects was low, and will need improvement in the coming years.

*3.3 Analysis of Enabling Factors*

For this analysis, a set of enabling factors was identified comprising input and output variables to quantify the performance of projects in terms of productivity, sustainability and replicability. A representative sample of 103 projects was used to perform a correlation analysis to derive the inferences. The sample projects selected were those which demonstrated good results during execution and performed well during various evaluations, i. e. those rated excellent/very good/good at the annual Group Monitoring Workshops (GMW). The GMW comprised independent evaluation by a group of experts and departmental officers. The information required for analysis was also supplemented through field visits to the project sites.

**Table 3** Extra-mural links according to type of S&T institution

| Type of institutions | Number | Percentage |
|---|---|---|
| Research institutions/national labs | 266 | 53 |
| Universities/colleges | 93 | 18 |
| Engineering institutions | 33 | 6 |
| Medical institutions | 23 | 5 |
| State government agencies | 81 | 16 |
| International organizations | 9 | 2 |
| Total | 505 | 100 |

*3.3.1 Enabling Factors*

As described next, a set of enabling factors pertaining to the project productivity, sustainability and replicability were identified. Many of these identified factors have emerged as the outcome of the individual initiatives and farsightedness of the implementing organisations (Raj, 2000).

1) Project Productivity
   i. Expertise of an organisation in the specific project related S&T area
   ii. Linking with S&T institutions for sourcing of appropriate technology, and for training of the project staff
   iii. Creating common technical facilities for production/infrastructure development
   iv. Providing in-built components for motivating and improving skills of beneficiaries and their involvement in project design and management
   v. Financial and material contribution by beneficiaries in project execution
   vi. In-house training of master trainers followed by their institutional training
   vii. High quality training curriculum and diversity in training materials used
   viii. Linking beneficiaries with financial institutions and micro-credit facilities
   ix. Building synergy and networking with other organizations in the area
   x. Using professional inputs in project design and

implementation

xi. Using innovative approaches in project design and implementation, including grass-root innovations carried out by local people

xii. Projects staff resides at the project site

2) Sustainability

i. Designing projects to become self-supporting after completion, through beneficiary's contribution and management

ii. Building strong component of project monitoring and evaluation

iii. Building capacities of the community in handling the project interventions

iv. Building supply chain systems by developing strong links with local markets, and beyond

v. Developing enterprise models and potential entrepreneurs during project execution

vi. Evolving suitable models for scaling up of the project interventions

vii. Supplementing income generation activities by support services and infrastructure development

viii. Integrating the project activity with other projects in the area

ix. Incentivizing proficiency and project delivery efficiency

x. Promoting socio-cultural mobilization to ensure acceptance of interventions, especially for projects located in remote and tribal areas

3) Replicability

i. Potential for replicability of a project enhances if the shortcomings in its design and implementation are identified through close monitoring and resolved under the follow-up actions

ii. Establishing direct links with existing networks and SHGs, such as farmers' forums, artisans' associations, in the project area

iii. Linking project-based intervention with State government policies and programmes

iv. Arranging media coverage to build awareness among potential replicators

### *3.3.2 Project Performance*

Project performance indicators were evaluated based on the following outcomes and using some of the significant output variables in Table 4.

The variables $y_1$, $y_2$, $y_3 \ldots y_{19}$ were quantified using the rating scale adopted for analyzing the projects covered under the study (Excellent=1, Good=0.5, Satisfactory=0.25, Poor=0). For the variable $y_{20}$, which represented an inclusive rating by a group of experts during the GMW meeting, the 'GMW rating scale' was used, i.e. Excellent= 1, Very Good= 0.5, Good= 0.25, Satisfactory=0.

*Composite Project Performance Index*

Assuming equal weightage to these variables, the six performance attributes are estimated using the following equations:

$$Technical\ Outcome\ Index\ (TI) = \frac{1}{3}\,(y_1 + y_2 + y_3) \quad (3)$$

$$Economic\ Outcome\ Index\ (EI) = \frac{1}{3}\,(y_4 + y_5 + y_6) \quad (4)$$

$$Social\ Outcome\ Index\ (SI) = \frac{1}{3}\,(y_7 + y_8 + y_9 + y_{10} + y_{11} + y_{12} + y_{13} + y_{14}) \quad (5)$$

$$Sustainability\ \ Index\ (SuI) = \frac{1}{3}\,(y_{15} + y_{16}) \quad (6)$$

$$Replicability\ Index\ (SuI) = \frac{1}{3}\,(y_{17} + y_{18} + y_{19}) \quad (7)$$

Finally, performance of the selected projects was quantified in terms of a *Composite Project Performance Index (CPPI),* using the above attributes:

$$CPPI = \frac{1}{5}\,(TI + EI + SI + SuI + RI + y_{20}) \quad (8)$$

If for a given project, all the five attributes score the value of 1, then the ideal value of *CPPI* will be 1. A correlation exercise was conducted between the

**Table 4** Profect pcrformance indicators

| | |
|---|---|
| | Technical outcomes |
| $y_1$ | Quality and extent of technology development and transfer/ training |
| $y_2$ | Extent of creation of technical facilities |
| $y_3$ | Number of papers/patents |
| | Economic outcomes |
| $y_4$ | Extent of income/employment creation among beneficiaries |
| $y_5$ | Number and soundness of business models/micro-enterprises established |
| $y_6$ | Extent of asset creation among beneficiaries/in the area |
| | Social outcomes |
| $y_7$ | Better health and nutrition |
| $y_8$ | Better access to water sources |
| $y_9$ | Better living conditions |
| $y_{10}$ | Betterment of children |
| $y_{11}$ | Better access to energy sources |
| $y_{12}$ | Betterment of women |
| $y_{13}$ | Environment impact |
| $y_{14}$ | Less drudgery |
| | Sustainability |
| $y_{15}$ | Follow-up system and its effectiveness |
| $y_{16}$ | Prospects of long-term viability of operations in terms of acceptability of facilities/utilization of technology in adoption/economic activities by beneficiaries |
| | Replicability and dissemination |
| $y_{17}$ | Extent of project replicated in other locations |
| $y_{18}$ | Dissemination among other prospective users |
| $y_{19}$ | Quality of documentation/extent of media coverage |
| | GMW rating |
| $y_{20}$ | Group Monitoring Workshops (GMW) rating |

**Table 5** Variables hypothesized to have relation to the performance

| |
|---|
| **Organization-related** |
| Location of organization & distance from the project site ($x_1$) |
| Age of organization ($x_2$) |
| Level of expertise ($x_3$) |
| Size of organization ($x_4$) |
| Past links with DST ($x_5$) |
| **Project Design Characteristics** |
| Qualification of the PI ($x_6$) |
| Type of activity ($x_7$) |
| Project budget ($x_8$) |
| Project duration ($x_9$) |
| Size of target beneficiaries ($x_{10}$) |
| Number of project staff employed ($x_{11}$) |
| **Implementation Approaches** |
| Sourcing of technology ($x_{12}$) |
| Creation of technical facilities ($x_{13}$) |
| Extent of beneficiaries involvement in project design and management ($x_{14}$) |
| Setting up of beneficiaries' organizations ($x_{15}$) |
| Extent of beneficiaries' mobilization ($x_{16}$) |
| Beneficiaries' material contribution to the project ($x_{17}$) |
| Mode of technology transfer ($x_{18}$) |
| Links established with institutions ($x_{19}$) |
| Links established with NGOs ($x_{20}$) |
| Links established with local bodies ($x_{21}$) |
| Links established with industry ($x_{22}$) |
| Links established with financial institutions/market ($x_{23}$) |
| Generation of publications (booklets/manuals/research papers/ patents) ($x_{24}$) |
| Training of beneficiaries ($x_{25}$) |
| Popularizing projects results and achievements through media ($x_{26}$) |
| Follow up mechanism after project completion ($x_{27}$) |
| **Performance Evaluation** |
| Number of monitoring/evaluation conducted ($x_{28}$) |

CPPI and each of the variables that are hypothesized to have relation to the performance as follows.

A high degree of association (implying correlation coefficients differing from zero with more than 95% level of confidence) was found with the variables: age of organization, level of expertise, size of organization, duration of the project, mode of technology transfer, extent of mobilizing beneficiaries, extent of beneficiaries involved in project design and management, links with financial institutions/market, and beneficiaries' material contribution to the project. The variables that were found to have moderate correlation (confidence level between 90-95%) with the CPPI are: project budget and setting up beneficiaries' organizations.

The societal projects present an altogether different challenge to the project implementing agencies. In such projects, overall design of the project and implementation strategies (including innovative approaches) play an important role than the traditional factors, such as high professional qualification of the PI, specialized laboratory facilities and infrastructure of the organization, etc. This explains a somewhat weak correlation (with confidence level of 75-90%) in cases of the variables 'distance of the organization from the project site ($x_1$)' and 'qualification of the PI ($x_6$)'.

The correlation coefficients for the other variables were as expected: larger organization and higher level of expertise can better manage a project; more accomplishments are expected in projects with longer duration; organizations adopting better and effective mode of technology transfer are likely to be more successful; greater mobilization or involvement of the beneficiaries would make a project more successful; establishing linkages between beneficiaries and the financial institutions/ markets would help the beneficiaries to become self-sufficient and thus make the project a success; and better material conditions of the beneficiaries would help them absorb benefits more effectively. Similarly for the moderately correlated explanatory variables, it may be argued that larger budget enables deployment of more productive resources, setting up of beneficiaries' organizations like SHGs would help them realize larger benefit from the project. Building technical facilities for technology transfer and establishing extra-mural links with S&T institutions will also enhance the outcomes of the project.

However, many of the variables were internally correlated and it was difficult to isolate which ones are actually influencing the project performance. For instance, budget size and duration were highly correlated (0.66), that is larger budget projects are of longer duration and thus difficult to say which one is influencing. A stepwise regression modeling exercise revealed that the most important variables influencing performance are $x_3$, $x_{12}$, $x_{13}$, $x_{15}$, $x_{23}$, and $x_{25}$. They together explain 47% of the variation in Y. The estimated value of c and the coefficients of $x_{14}$ and $x_{23}$ are significant at less than 1% level and the coefficients of $x_2$, $x_5$, $x_{17}$ and $x_{28}$ are significant at 9-12% level. Because of high adjusted R-squared value (0.47), the estimated linear model has high predictive power that may be used for policy purposes. For example, project performance may be improved by establishing greater market linkages, by mobilizing beneficiaries, by asking contributions from the beneficiaries, etc.

## 4. Summary and Discussion

It was observed that older and large-size organizations with high level of expertise and past links with the DST seemed to be having proved as good performers. Therefore, to promote the participation of new and smaller organizations in the Societal Projects, it may be prudent to link them in their formative years with the well-established and performing organizations so as to enable them share the expertise and resources of their senior partners.

The projects which employed a technology based on modification of beneficiaries' traditional practices or developed in-house by the organization seem to perform better than the technology developed outside or borrowed from another institution. The effectiveness of mode of technology transfer has emerged as one of the most enabling factors in influencing the overall impact of the projects. Therefore, quality of training staff and material used, creation of easily useable technological facilities for training and production and in-situ transfer of know-how is of critical importance for the project-based grassroots interventions.

The projects dedicated to technology transfer based on training programmes are relatively more productive than those pertaining to 'technology development' and 'technology development and transfer'. This shows that the main forte of the Projects has been 'technology transfer and training'. This may be because the projects on technology development per se are more lab-based and require specialized technical background. Link with appropriate S&T institutions is desirable to achieve the desired outcomes in such projects.

Links with financial institutions and the market has emerged as the most critical enabling factor for the sustainability of the projects. This means that the project designer at the outset should ensure pursuing these linkages in the first place. The projects which facilitated monetary and material contribution from the target beneficiaries seem exhibiting a higher level of performance, indicating this aspect should be considered as an essential component of the project proposals.

The following three factors related to the target group participation have been found to be of immense importance in enhancing productivity of projects:

(i) Extent of all around mobilization of beneficiaries through community organizations, Panchayats and door-to-door campaigning,
(ii) Beneficiaries involvement in project design and management and in follow-ups, and
(iii) Organizing beneficiaries in the form of self-help groups/similar organizations.

Successful completed projects indicated cost and risk sharing with local beneficiaries through the formation of local self help group system/development committee/co-operative system for commercialization towards generation of sustainable livelihoods. The study's general conclusions is most of the projects led to various types of publications (booklets/manuals/training material/research papers), which is a very important source for preservation of knowledge generated under the project mode and for wider dissemination among scientists, project implementing organizations and young researchers.

## 5. Conclusion

S&T based societal projects definitely provide a useful vehicle for integrated and inclusive development for community benefits. The analysis shows that such projects not only bring tangible benefits to the target beneficiaries and the area but also empower them in deriving benefits of the technological advancements.

Based on the above analysis, it is recommended that a package of strategies can be adopted for the projects to be more focussed, productive and sustainable over the time, particularly for development of sustainable micro-enterprises, and for potential replication and scaling up. These may include interventions built around strategic actions, such as:

1. Sourcing of technology/know-how from proven sources
2. Integrating capacity building, training and technology transfer
3. Mobilizing beneficiary participation and contribution
4. Working with an enterprise model and ensuring sustainable links with financial institutions and market
5. Strengthening extra-mural links with S&T institutions
6. Monitoring, evaluation and follow-up
7. Replication, dissemination and scaling up
8. Reaching out to organizations and bringing operational synergy as well as networking for achieving sound management of supply chain
9. Improving project dispersal among States, especially targeting economically backward districts
10. Including innovative approaches

The analysis presented in this paper provides an insight into the functioning of societal projects in India, and in the DST-supported projects in particular. The analysis also presents a methodology to the funding agencies as well as to the planners in designing S&T based societal projects keeping in view the critical enabling factors so that the returns from the investments are optimally utilized and to make these projects successful in terms of ensuring their replicability and utilisation in various sectors of sustainable development.

## Acknowledgements

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# Re-evaluation of the Introduction of the Clinical Resident Training System and Its Effect on Medical Offices (*Ikyoku*) in Japan

Yuko Ito[1,2*], Hiromi Saito[3]

**Abstract**
Due to the introduction of the new Clinical Resident Training System introduced in 2004, the destination where interns do residency changed in Japan. Before this system, university hospitals received 70 % of the interns, but by 2008, dropped to 50 %. This independence from university hospitals cause to decrease number of interns attached to medical offices (*Ikyoku*). A questionnaire survey targeting hospital doctors was carried out, and differences between "doctors attached to medical offices" and "doctors not attached to medical offices" were then analyzed. From this, the role of medical offices was hypothesized. As a result, it was suggested that medical offices were places for doctors in specialized fields to write papers in a foreign language or Japanese, in order to widely disseminate their medical achievements. There is concern that fewer papers may be submitted and/or the level of medical services may decrease due to this reduction in human resources in medical offices.

**Keywords**: Clinical Resident Training System, Hospital Physicians, Human Resources, Maldistribution

## 1. Introduction

The Universal Health Care System in Japan was introduced in 1961, with basic medical services provided equally to all at a fixed cost. The health of the Japanese people is recognized as being maintained by this system, and Japan now has the highest longevity rates in the world. Many countries are considering the introduction of a similar universal health care system (Reddy et al., 2011; Chongsuvivatwong et al., 2011; WHO, 2010).

Recently, however, various issues, such as an increase in medical costs due to an aging population, the changing disease profile of society, and the rapid development of medical technology, have been threatening the Universal Health Care System in Japan. Furthermore, it is reported that a shortage of doctors has led to practicing doctors being exhausted due to uneven geographical distribution and prolonged working hours (Yasunaga, 2008; Wada et al., 2010).

Although such issues must be resolved in the Japanese medical care system, other countries face similar problems (Horton, 2010). In Southeast Asia, uneven regional distribution of human medical resources (including doctors) is considered to be a problem (Kanchanachitra et al., 2011), and according to written reports presented by the WHO (2006), proper distribution of human medical resources (such as doctors) in specialized fields may be a determining factor in the implementation of a medical care system.

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Therefore, surveys and analyses of conditions (environment, activity, etc.) of doctors, who are the core of human resources in the medical care system are very important in the consideration of improvements to the medical care system and policy planning.

In this study, we focus on the Clinical Resident Training System in Japan and assess the effect that introducing the system has had on doctors' behavior through a questionnaire survey. In addition, we will assess the effect of the introduction of the Clinical Resident Training System.

## 2. Political Background

### *2.1 Effects of the Introduction of the New Clinical Resident Training System*

In Japan, the new Clinical Resident Training System was introduced in 2004 (MHLW, 2010). The introduction of this system greatly affected the residency system of interns because of the addition of a clause stipulating that "two years or more of compulsory residency is required for doctors who wish to engage in the medical care."

Residency became compulsory due to the following reasons. (1) Problems in earlier training, such as little contact with community healthcare, on-the-job training biased toward specialized hospital departments, and treatment of the illness not the person; (2) poor working conditions for many interns where they cannot concentrate on their residency and are required to seek part-time work; (3) on-the-job training mainly carried out at an affiliated college or hospitals, and insufficient evaluation of training contents or achievements; and (4) the need for improvement.

The largest change in the new system was the method for determining where residency was to be provided. Previously, interns were first attached to the medical offices (Ikyoku) of their affiliated colleges or university, and the medical offices determined the destination (medical offices or related hospitals) where the interns would do residency. Under the new system, because it takes into consideration requests from both interns and the hospitals where they want to do residency, the process is computed (operated by the Japan Residency Matching Program) (Kozu, 2006).

As shown in Fig. 1, this led to a change in the destinations where interns do residency when compared with the period before the introduction of the new system (in 2003) (MHLW, 2010). Before the system's introduction, 70% or more of the interns did residency at university hospitals, whereas after the introduction of the system, this rate dropped. Since 2006, the rate of those with residency at clinical resident training hospitals, which include general hospitals, has only slightly increased.

Although the original purpose of the introduction of the system was to bring into effect a shift in the destination where interns do residency from university hospitals in specialized fields to general hospitals where emphasis is placed on primary care, the relationship between doctors and the medical offices of university hospitals changed drastically.

This shift has resulted in a shortage of doctors at university hospitals and a reduction in the power of the medical offices of university hospitals.

### *2.2. Traditional Role of Medical Offices in Japan*

We will briefly explain the role played by medical offices at universities in Japan. Medical offices are

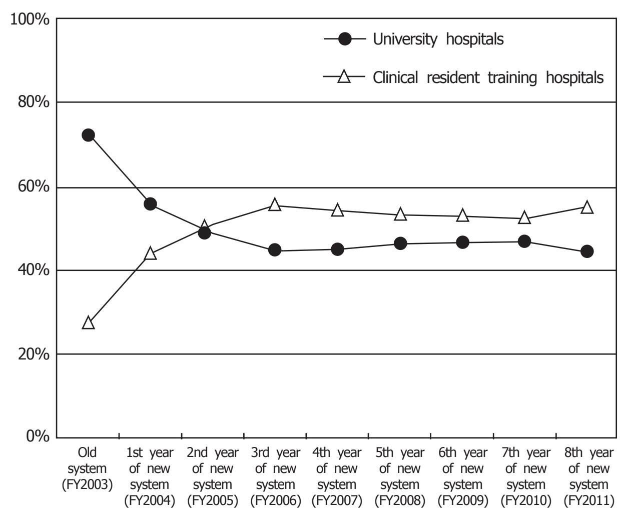



**Figure 1** Change in destinations where interns do residency

a unique organization in Japan, functioning as a control center of medical education, medical care activities, and research activities (Otaki, 1998). In addition, medical offices combine the diagnosis and treatment department of a university hospital with the university's clinical course and, in effect, have decision-making powers regarding appointments to the medical offices at related hospitals. In this way, they exercise control over personnel matters (Otaki, 1998).

With the introduction of the new Clinical Resident Training System, the location where residency is provided is determined without going through the medical offices, and the process is thus considered to have weakened the authority of the medical offices over personnel matters and increased the independence of interns.

According to a questionnaire survey targeting medical offices carried out in 2008, 76.6% of the valid responses (1,024) from medical offices reported that they had "discontinued or suspended the dispatch of doctors" to related hospitals after the implementation of the new Clinical Resident Training System. This was due to a shortage of doctors and led to restrictions in medical care and/or the closing of the diagnosis and treatment departments in related hospitals (Mori, 2008).

It is assumed that the weakening of authority over personnel matters held by medical offices led to a loss in their ability to "consolidate and distribute human resources." The problem is considered the result of focusing only on the negative aspects of medical offices and failing to sufficiently analyze the role of medical offices in the medical care system.

Consequently, a questionnaire survey targeting hospital doctors was conducted, and the characteristics of doctors attached to medical offices were analyzed from the results.

We evaluated the functions of medical offices based on the results of this questionnaire survey.

## 3. Survey

A questionnaire targeting hospital doctors (excluding practitioners) from among physician monitors (3,531 monitors, as of January 2010) in cooperation with SPiRE, Inc., was carried out over the Internet (Ito & Nagano, 2011).

The questionnaire comprised 35 questions. It included hospital characteristics (hospital type, number of beds, administrative entity, work environment, IT infrastructure, etc.) and respondent characteristics (gender, age, specialty, service year, years of experience as a clinician, medical doctorate holder, certified medical specialist, attached to a medical office, etc.). In addition, the questionnaire surveyed the experience of and attitudes toward conducting clinical research.

The survey period was between February 15 and 23, 2010, and the number of questionnaires collected was 684 (respondent rate: 19.4%).

## 4. Results and Discussion

In response to the question, "Do you belong to a medical office of a university?" 55.8% (382) answered "Yes," and 44.2% (302) answered "No."

We examined whether there were differences between "Attached to a medical office" and "Not attached to a medical office" using the Wilcoxon rank sum test (Table 1). Significant differences were found in "age," "number of hospital beds where the intern works," "working at a national/independent hospital," "working at a medical corporation hospital," "service years," "medical doctorate," "certification of medical specialist," "experience in publishing papers in medical magazines written in a foreign language, etc.," and "experience in publishing papers in medical magazines written in Japanese, etc."

Regarding "age" and "service years," average values of "doctors attached to a medical office" were slightly lower than the average values of "doctors not attached to a medical office."

Compared with doctors "not attached to medical offices," most doctors "attached to a medical office" work at national/independent hospitals, have a medical doctorate, and are certified medical specialists. Furthermore, they have experience in publishing papers in medical journals in both a foreign language and Japanese.

**Table 1** "Attached to a medical office" vs. "Not attached to a medical office"

| | Not attached to a medical office | | | Attached to a medical office | | | |
|---|---|---|---|---|---|---|---|
| | N | Mean | Median | N | Mean | Median | |
| Age | 302 | 48.841 | 45 | 382 | 44.424 | 45 | *** |
| Male | 302 | 0.821 | 1 | 382 | 0.887 | 1 | ** |
| Bed | 302 | 189.040 | 60 | 382 | 426.204 | 400 | *** |
| NIAA hospital | 302 | 0.046 | 0 | 382 | 0.204 | 0 | *** |
| M hospital | 302 | 0.089 | 0 | 382 | 0.131 | 0 | * |
| PMI hospital | 302 | 0.050 | 0 | 382 | 0.071 | 0 | |
| SI hospital | 302 | 0.020 | 0 | 382 | 0.034 | 0 | |
| MC hospital | 302 | 0.507 | 1 | 382 | 0.314 | 0 | *** |
| Service year | 302 | 9.248 | 7 | 382 | 7.393 | 7 | *** |
| MD | 302 | 0.391 | 0 | 382 | 0.584 | 1 | *** |
| MS | 302 | 0.573 | 1 | 382 | 0.825 | 1 | *** |
| FL article | 302 | 0.328 | 0 | 382 | 0.552 | 1 | *** |
| J article | 302 | 0.642 | 1 | 382 | 0.835 | 1 | *** |

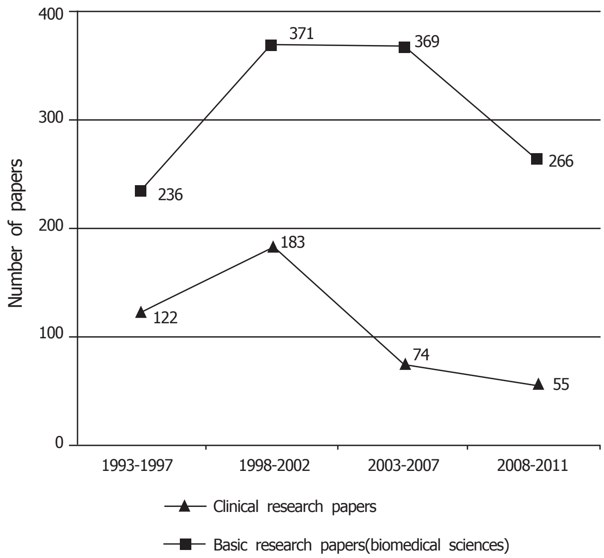
Age: Age, Male: Male, Bed: Bed number, NIAA hospital: National/Independent hospital, M hospital: Municipal hospital, PMI hospital: Public medical institution hospital, SI hospital: Social insurance related association hospital, MC hospital: Medical corporation hospital, Service year: Service years, MD: Medical doctorate, MS: Medical specialist, FL article: experience in publishing papers in medical journals written in a foreign language, etc., J article: experience in publishing papers in medical journals written in Japanese, etc.

Based on these results, the function of medical offices was considered. We found that many doctors with a medical doctorate and certified as medical specialists were "attached to a medical office." In this correlation, two possibilities have been proposed: (1) the medical office environment is advantageous to the acquisition of a medical doctorate or certification as a medical specialist, and/or (2) a medical doctorate or certification as a medical specialist is advantageous in building a career as a doctor attached to a medical office.

Furthermore, since many doctors "attached to a medical office" have "experience in publishing papers in medical journals, etc., in a foreign language and/or Japanese," it is assumed that the medical office environment is advantageous for writing and publishing "papers for medical journals, etc.," and that medical offices stimulate such incentives. Regarding the accreditation criteria for medical specialists, since "a paper as the lead author" in a related field is required, acquisition of certification as a medical specialist may be an incentive for "writing papers in Japanese." In some cases, writing papers in a foreign language is required for acquisition of a medical doctorate.

From the above, a central role of medical offices is to function as a place where doctors in specialized fields can write papers in a foreign language or in Japanese. This can be considered to have led to the wide dissemination of advanced medical knowledge throughout Japan and to have raised the level of medical care in Japan. Consequently, there is concern that the shortage of human resources in medical offices due to the introduction of the new Clinical Resident Training System may result in fewer papers being submitted to medical journals. As shown in Figure 2, there have been reports that clinical research papers have been drastically decreasing in number since 2003, as compared with basic research papers (Takatori, 2008; Tatsumi, 2012; Murashige et al., 2011). This might indicate the need for further surveys and a reevaluation of the role of medical offices.

In addition, we should mention that the National University Corporation Law was introduced in 2003. Under this law, National Universities were granted independence from Government rules on April 1, 2004 (MEXT, 2003). This reform may also have played




Clinical research papers include published papers in the New England Journal of Medicine, the Lancet, and JAMA. Basic research papers include those published in Nature Medicine, Cell, and the Journal of Experimental Medicine.
* This figure is modified from Tables in referred papers (Takatori, 2008; Tatsumi, 2012).

**Figure 2** Change in number of clinical research papers and basic research papers published by Japan

a role in the decrease in the production of academic papers, because of changing workload of university faculty who engage in teaching as well as conducting research than before (Watanabe, 2011).

We presume that decreasing number of papers might be caused by (1) shortage of human resources in medical offices, (2) time reduction for research activities of faculties in medical schools of National Universities, and (3) any other factors. However, we should carefully examine it more and more

Our results seem to show the negative effects of introducing the Clinical Resident Training System in Japan. It caused a shift of residents away from university hospitals and toward non-university hospitals. Interestingly, residents at non-university hospitals were shown to have higher levels of satisfaction with the residency system, clinical skills training, income, and educational environment (Nomura et al., 2008; Tokuda et al., 2010). Therefore, the current situation may remain unchanged.

The shift undermines the influence of medical offices and could result in a maldistribution of doctors and reduced research activity in clinical research. It is reported that the geographic distribution of doctors got more uneven after 2004 (Toyabe, 2009) and that the maldistribution of doctors as a consequence of urbanization has increased (Tanihara et al., 2011).

In 2007, the Japanese government decided to increase the number of medical students every year from 2008 to combat the shortage of doctors. However, the true nature of the problem is not simply a matter of a shortage in the number of doctors but also the maldistribution of doctors. Tanaka has warned about the possibility of a surplus of doctors in the future in Japan (Tanaka et al., 2011).

## 5. Conclusion

We propose a reevaluation of the role of medical offices in Japan's medical care system. This does not mean that medical offices at university hospitals should be restored to their former status. Rather, the role of non-university hospitals should be enhanced and some consideration should be given to their having a part to play in the distribution of doctors and in conducting clinical research in the future.

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# R&D on Nuclear Safety and Severe Accident Mitigation in China

X. Cheng[1]

**Abstract**
Recently China issued an ambitious program of mid-term nuclear power development. It is expected that the total nuclear power installation will be around 200GW by 2030 and around 400GW by the middle of this century. Nuclear safety has been well recognized having the top priority in the nuclear power development, especially after Fukushima accident.
Nuclear safety and severe accident research activities have been growing rapidly in recent years. Numerous projects financed by the Chinese central government, local government and nuclear industries were launched. In the frame of the "National Large Scale Project", many projects were initiated and research infrastructure was constructed. More recently the National Energy Administration approved research projects in direct connection with the Fukushima accident. According to the newly issued Nuclear Safety Plan a much larger scale of infrastructure and community will be established for nuclear safety research.
The nuclear safety research community is expanding strongly in recent years. It covers nearly nuclear industries, research centers and universities. To some degree the R&D activities in China are well coordinated. There is tight collaboration and interaction among this community. This paper gives an overview about Chinese nuclear power technology development and the R&D activities in nuclear safety and severe accident mitigation. Two R&D projects ongoing at Shanghai Jiao Tong University are selected as examples, to outline some features of nuclear safety research in China.

**Keywords**: R&D, Nuclear Ssafety, Severe Accident, China

## 1. Introduction

Nuclear power has been accepted worldwide as one of the key energy sources due to its advantages with respect to environment protection, economic competitiveness and power supply stability. Since the start of the economic reform in 1970s, the Chinese economics has been undergoing rapid development. One of the bottlenecking issues in the Chinese economics development is sustainable and environment friendly energy supply. By 2020 the electricity demand in China is expected to become double as compared to 2010 (WNA 2012). For the time being, more than 80% of electricity production comes from fossil fuel. China recently overtook the USA as the world's largest contributor to carbon dioxide emissions (U.S. DOE 2012). It is predicted that China's share in global coal-related emissions will grow by 2.7% per year and reach 9.3 billion tones in 2030. Economic lost due to pollution is estimated up to 6% of GDP (World bank 2007).

Development of environment friendly energy supplies becomes thus a crucial issue in the future Chinese economy. Due to the well known limitation in renewable energy and hydro-power, nuclear power is

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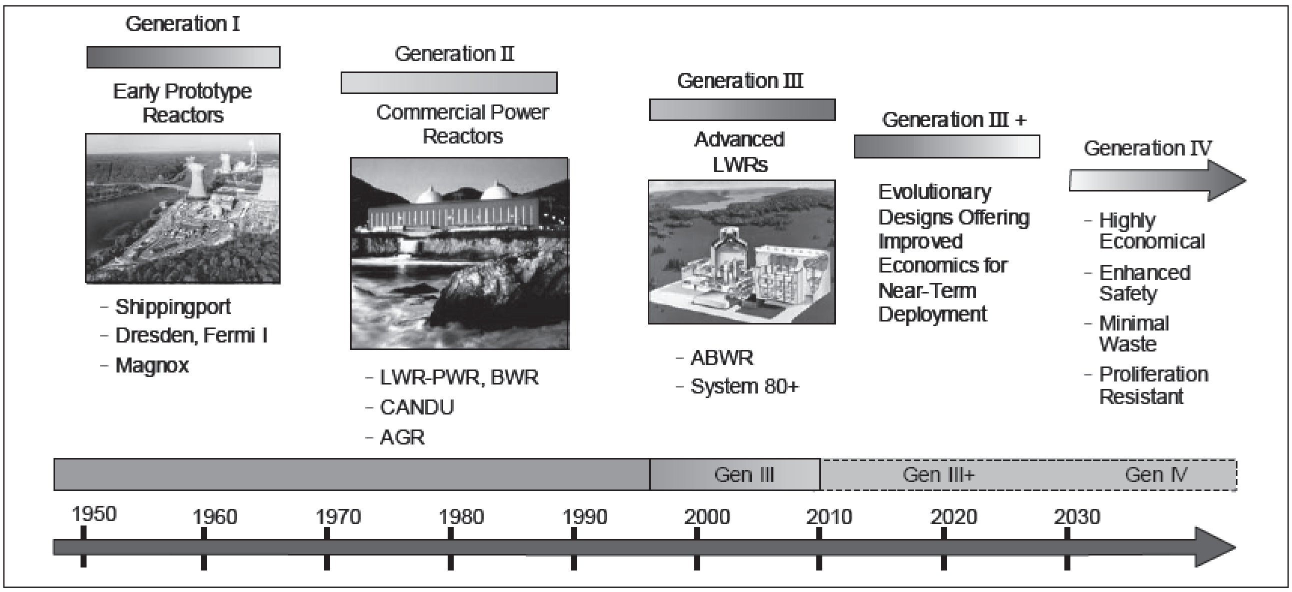
considered as a safe, clean, sustainable and economic energy source. In November 2007, China issued an ambitious program of mid-term nuclear power development (NDRC, 2007). A new target was issued most recently (Xinhua News Agency, 2012a). It is expected that the total nuclear power installation will reach 88 GW with 58 GW in operation and 30 GW under construction by 2020 (China Energy News, 2012). According to the estimation of the Chinese nuclear experts, the nuclear power installation will be around 200GW by 2030 and around 400GW by the middle of this century (WNA, 2012). That will make about 25% of the total electricity production at that time.

From the technology point of view, four generations of nuclear systems are identified by the international nuclear community (U.S. DOE, 2002), as illustrated in Figure 1.

The first generation (GEN-I) was the products of 1950's and early 1960's. They consist mainly of demonstration plants of small power. Based on the experience gathered in the first generation and applying standardization the second generation (GEN-II) was established. The most nuclear power plants operating nowadays worldwide, or all nuclear power plants operating in China, belong to the second generation. After the accident of Three Mile Island (TMI) and Tschernobyl intensive efforts were made to improve the safety features of the second generation nuclear power plants. Compared to the second generation, the third generation (GEN-III) of nuclear power plants owns a much higher safety level. The core melt frequency is lower than 10-5 per reactor and per year, and severe accident mitigation measures and related guidelines are integrated into the GEN-III systems. Various types of GEN-III light water reactors (LWR) are now available. Two of the most representative types of pressurized water reactors (PWR) are AP1000 of Westinghouse (Cummins et al., 2003) and EPR of AVERA (Czech et al., 2004), both are now under construction in China. One of the common features of the GEN-III reactors is their enhanced safety performance. This is achieved using different approaches, from the improvement of human reliability to the introduction of completely new subsystems. Passive safety systems are widely applied, especially in the AP1000 concept of Westinghouse. In China, passive safety systems are recommended to be applied wherever it is feasible. In the last three decades, extensive R&D activities were carried out worldwide to enhance safety of NPPs and




Source : U.S. DOE (2002)

**Figure 1** Nuclear power technology development to develop severe accident mitigation systems. Since the beginning of this century, the priority of safety and severe accident research has been set back in favor of other features such as sustainability and economics, and in favor of the development of innovative nuclear systems of the fourth generation (GEN-IV).

The Fukushíma accident rekindles the interest of international nuclear community in safety and severe accident R&D. The importance of and the needs for strongly enhanced synergizing international research activities are well recognized to further improve nuclear safety culture and to stimulate safety research (Yamada, 2012). The ambitious program of nuclear power development in China requires high safety level, motivates R&D in safety and severe accident mitigation and attracts interests and attentions of international community for stronger interaction and collaboration with Chinese nuclear community.

## 2. Chinese Nuclear Power Technology

Based on the experience gathered worldwide in the nuclear power development of the past 50 years, attention has be paid in China to the selection of reference technology lines and to the realization of self-reliance technology, to ensure a safe, economic and sustainable development of nuclear power.

### *2.1 Selection of Technology Lines*

For the time being, 15 units have been put into operation with a total installed capacity of 12.3 GW and 26 units are under construction with an installed capacity of 31.0 GW (Wang, 2012). Although all these units consist of water-cooled reactors, they are from different technology lines of GEN-II and GEN-III, e.g. Chinese small power PWR, Canadian CANDU, French 900 MW class PWR and its modified CPR1000, Russian WWER, AP1000 of Westinghouse and EPR of AREVA. The existing experience emphasizes the necessity to reduce the number of technology lines and to define a few major technology lines for the future Chinese nuclear power plants. Considering the Chinese specific situation and the experience gathered in the national and international nuclear community, it is well agreed and decided that pressurized water reactor of GEN-III will be the main reactor type for the future Chinese nuclear power generation, at least for the mid-term. Passive safety systems should be a key feature of the Chinese GEN-III PWR and need to be implemented wherever it is feasible. In addition, it should fulfill the following requirements (Ouyang, 2008):

a) Economical competitiveness;
b) Operating reliability and easy maintainability;
c) Compliment with the latest safety codes for severe accident prevention and mitigation measures issued by China National Nuclear Safety Administration (NNSA) and IAEA;
d) Digital instrumentation and control system;
e) Advanced human factor engineering technique and advanced main control room.

The above technology requirements justify the choice of AP1000 technology of Westinghouse as one of the reference technology line for the Chinese GEN-III PWR.

### *2.2 Process to Self-reliance Technology*

As soon as the future technology lines are defined, extensive efforts should be made to develop self-reliance technology. To achieve the mid-term target, China issues twofold strategy (Cheng et al., 2009). In one side construction of NPPs based on existing GEN-II PWR technology will be continued. Modification of the GEN-II PWR power plants will be undertaken, especially with respect to safety performance. In the other side large efforts are made to accelerate the self-reliance process of the GEN-III PWR technology. The Chinese government has issued a National Large-Scale Pogram to develop technology of advanced large-scale pressurized water reactors (The State Council, 2006) and to accelerate the self-reliance of the Chinese nuclear technology. The nuclear power self-reliance program has been launched with Sanmen project in Zhejiang Province and Haiyang project in Shandong

Province as supporting projects (Ouyang, 2008). By 2017, a prototype reactor of the Chinese self-reliance GEN-III PWR with 1400 MW electric power (CAP1400) will be constructed and put into operation (Zheng, 2012).

Realization of self-reliance nuclear technology requires high quality coordination, including various institutions for design, research, manufacture and education. For this purpose a new organization, the State Nuclear Power Technology Corp. LTD (SNPTC), was founded in 2007. SNPTC is responsible for the self-reliance of the Chinese GEN-III PWR technology and has established sub-companies for research, design and manufacture, respectively (www.snptc.com.cn).

In the frame of the "National Large-Scale Program", comprehensive R&D activities on severe accident prevention and mitigation are proposed. They include both fundamental and engineering aspects. Some R&D studies focus directly on the design and licensing requirements of CAP1400, whereas some other activities deal with basic phenomena involved in severe accident procedures, e.g. phenomenological studies on fuel-coolant interaction, hydrogen distribution and combustion.

*2.3 Actions after Fukushima Accident*

The Fukushima accident gives fatal impact on and consequence for nuclear power. On the other hand, it forces the international nuclear community to learn lessons for safer and more reliable nuclear power systems. The importance was well recognized of further enhanced research in safety culture, severe accident prevention and mitigation and international collaboration (Yamada, 2012). Most of the countries with nuclear power plants undertook actions and responded to Fukushima accident immediately. Directly after Fukushma accident, the Chinese State Council made four decisions (Wang, 2012):

a) To immediately organize comprehensive safety examination (CSE) to nuclear power plants to identify weakness and take corresponding measures if necessary;
b) To improve management and to ensure safe operation by utilities and to strengthen regulation procedure by regulatory body;
c) To apply the most advanced standards to review and to examine all NPPs under construction;
d) To establish Nuclear Safety Plan (NSP). No new NPP will be approved until NSP is issued.

The main purposes of CSE are to evaluate the conformity of the exiting NPPs with the current Chinese regulations and standards, to identify the potential safety weakness of the existing NPP and to propose requirements to enhance their safety. The main issues of CSE cover the NPP capability against flooding, earthquake, fire, state blackout, emergency power losing, multiple external nature hazards and severe accidents mitigation capability. Furthermore, public information and communication, environmental monitoring system and emergency response system are also subjects of CSE. The main outcomes of CSE are:

a) The safety of the most Chinese NPPs meets the Chinese nuclear safety regulations and the safety requirements defined by IAEA nuclear safety standards;
b) Prevention and mitigation of severe accident of NPPs have been taken into consideration and managed effectively during design, manufacturing, construction, commissioning and operation in new Chinese NPPs;
c) Based on the lessons learned from the Fukushima accident, additional research works are recommended in order to further enhance the nuclear safety, especially in the fields of extreme external events, severe accident and emergency Management.

Shortly after Fukushima accident, the China National Energy Administration initiated several projects dealing with safety and severe accident mitigation aspects, also directly in connection with Fukushima accidents (NEA, 2012; WNA, 2012), such as:

- Passive emergency power supply;

- Passive cooling of refueling water pool;
- Passive containment cooling;
- Hydrogen control systems;
- Enhanced resistance against earthquake and other external disasters;
- Numerical simulation platform for severe accident;
- Robot for emergency application under severe accidents;
- Emergency treatment of radioactive water.

In October 2012, the Nuclear Safety Plan (NSP) was approved by The State Council (XinHua News Agency, 2012b; WNA, 2012), which defines tasks and targets by 2015 and 2020, respectively. One of the main goals by 2020 is to practically eliminate the possibility of large release of radioactive materials. During the first period, five key projects are proposed. One of them is related to R&D in nuclear safety and severe accident prevention and mitigation. This project consists of two parts. The first part is devoted to the development of research capability and infrastructure, whereas the second part to scientific tasks covering more than 100 individual subprojects. International collaboration is identified as one of the key measures to successfully carry out these subprojects.

## 3. R&D Activities

According to the 'defense in depth' safety concept in nuclear power plants, the main safety measures can be divided into three categories;

- Normal operating conditions. Here the focus is on the reliability of operating systems, operating personals, safety culture and management. It covers the procedure of design, construction and operation of nuclear power plants. With these measures the occurrence of abnormal and accidental events are reduced as far as possible.
- Mitigation of design based accidents and prevention of severe accident. In case of accident occurrence, safety systems are put into operation, to guarantee the shutdown of reactor and safe removal of decay heat. To achieve these goals, nuclear power plants have reactor shutdown system and core safety injection systems (CSIS).
- Mitigation of severe accident. The objectives of severe accident mitigation systems are to minimize the consequence of severe accidents, to guarantee the integrity of containment (the last barrier to confine radioactive materials) and to avoid large release of radioactive materials to environment.

In China R&D activities in all three categories are ongoing. Very strong activities are focused on core safety injection system and severe accident mitigation. Some key procedures involved in severe accident are summarized in Table 1. It starts from core melt process. The core melt collected in the lower plenum of the reactor pressure vessel (RPV) and forms a melt pool. The formation and behavior of melt pool in the lower plenum is a key process to be considered in the mitigation measures. In GEN-III LWR, the applied severe accident mitigation concepts can be divided into two classes. In one class, the mitigation system focuses on the integrity of RPV and confines melt inside the RPV, the so called in-vessel retention (IVR) concept. The other concept allows the failure of RPV and has a core catcher outside the RPV, the so called ex-vessel core catcher concept. Both concepts exist in the Chinese GEN-III PWR. The AP1000 and the further developed CAP-series apply IVR concept (Zheng, 2012; WNA, 2012), whereas the VVER and EPR constructed in China use ex-vessel core catcher concept (Czech et al., 2004;, WNA, 2012). Independent of severe accident mitigation concepts, there are several common and important processes, such as hydrogen safety, steam explosion and containment cooling and integrity.

Table 1 shows the author's personal evaluation of the processes according to the amount of previous R&D studies worldwide, knowledge at present stage and the importance for future Chinese R&D. The evaluation score ranges from 1 to 3 and stands for 'low' to 'high'. The score '3' means a large number of previous studies, or sufficient existing knowledge or high importance for Chinese future R&D. For all phenomena, moderate to extensive R&D activities

**Table 1** Main SA processes and their status

| Phenomena | Previous R&D | Existing knowledge | Importance for China |
|---|---|---|---|
| Core melt process | 2 | 2 | 1 |
| Melt pool behavior | 2 | 1 | 2 |
| In-vessel retention, IVR | 2 | 2 | 3 |
| Ex-vessel core catcher | 3 | 2 | 2 |
| Fuel coolant interaction | 3 | 1 | 1 |
| Hydrogen safety | 3 | 2 | 3 |
| Containment cooling | 2 | 2 | 3 |

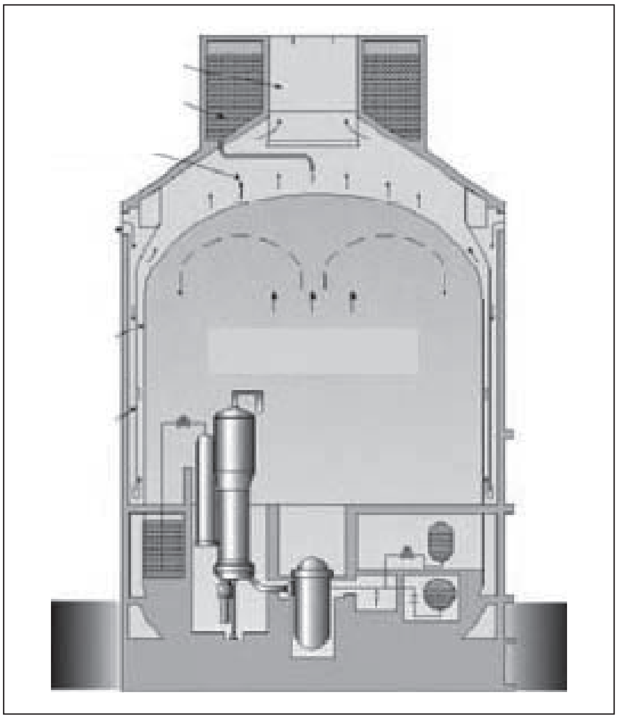
were carried out in the past worldwide. However, there exists deficiency in knowledge related to all phenomena. Considering the present situation in China, three phenomena are considered by the author as having the highest priority, i.e. IVR related phenomena, hydrogen safety and containment cooling and integrity.

Research activities on nuclear safety and severe accident mitigation are being carried out at various Chinese institutions, e.g. large scale integral test facilities for core safety injection system and containment cooling are under construction at the State Nuclear Power Research Institute of SNPTC (Chen, 2012; SNPRI, 2012), a large R&D program on IVR related phenomena has been established at China Nuclear Power Research Institute (CNPRI, 2012) of China Guangdong Nuclear Power Corporation, and some other research works are launched at Nuclear Power Institute of China (NPIC, 2012; Lu et al., 2008) of China National Nuclear Corporation related to safety performance improvement in accident prevention and mitigation. In the following, two R&D projects on severe accident mitigation at Shanghai Jiao Tong University are selected and presented in this paper.

### *3.1 Passive Containment Cooling*

As the last safety barrier containment integrity has achieved strong attention of the Chinese nuclear community. Passive containment safety systems have been widely applied to advanced water-cooled reactors. As a long-term passive decay heat removal AP1000 of Westinghouse or Chinese CAP-series use the passive water injection flow, natural convection of air combined with thermal radiation to remove the decay heat from the containment to outside. For the short-term (the first 72 hours) water-film evaporation heat transfer plays the dominant role.

Figure 2 shows schematically the passive containment cooling system of AP1000 and the Chinese CAP series. It consists of two containment shells, i.e. the inner steel containment shell and the outer concrete containment shell. Between both containment shells there exists a baffle plate, which divided the gap into two flow channels. A water tank locates at the top of concrete containment shell. Under accident conditions, water injection from the water tank is initiated to the top of the inner steel containment shell. It flows downward along the inner containment shell, forms water film, evaporates and transfers heat. In addition, natural convection of air is produced due to buoyancy effect. In the inner flow channel with higher temperature, air mixed with evaporated steam flows upwards, whereas in the outer flow channel air enters into the channel at the top opening, flows



Source : Cummins et al. (2003)

**Figure 2** AP1000 containment and its passive cooling system downwards and turns over at the channel bottom. This natural convection of air contributes also to the heat removal from the containment to environment. Water tank is sufficient for water injection of 72 hours. During these 72 hours heat transfer through water film evaporation plays dominant role. After the termination of water injection, natural air convection or other measures have to guarantee sufficient containment cooling.

Heat removal via water film evaporation is strongly affected by the water film behavior such as water film thickness, coverage rate and partial pressure of steam. Up to now water film behavior under prototypical conditions is still insufficiently understood, e.g. under count-current air flow conditions.

One of the key features of heat transfer via air convection is the strong effect of buoyancy and interaction with thermal radiation (Cheng & Mueller, 1998; Cheng et al., 2001; Cheng et al., 2001). Convective heat transfer capability could be significantly reduced under buoyancy effect and needs detailed investigation. Therefore, investigations on fundamental heat transfer mechanism and heat transfer capability are carried out with both experimental and numerical approach at Shanghai Jiao Tong University. Several test facilities have been constructed to achieve different purposes, as summarized in Table 2.

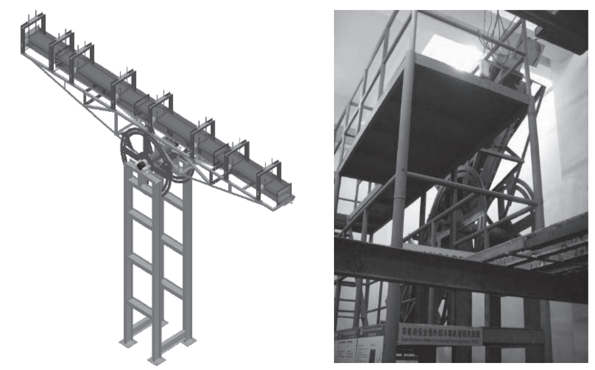
**(a) Natural Air Convection**

The experimental work with MICARE (MIx Convection of Air in Rectangle Channel) test facility belongs to fundamental features with the main objectives to study natural air convection behavior and heat transfer. Sophisticated measurements provide test data of three-dimensional velocity profile for improved understanding of phenomena and validation of models and simulation codes. Figure 3 shows the test section MICARE, which is a square flow channel with the cross-section up to 400 mm x 250 mm. One side of the channel is electrically heated. The heated plate is designed to achieve well uniform distribution of heated wall temperature. The orientation of the flow channel can be changed arbitrarily. The test section has a total height of 8 m. The test section can be connected to an auxiliary equipment to realize a forced flow of air into the test channel. The wall temperature can be varied up to 200°C. The test facility is equipped among others with a large number of thermocouples to measure the distribution of wall temperatures. Hot-wire anemometer and thermocouples are applied to measure the air velocity and air temperature distribution in the flow channel (Yu, 2012a; Yu et al., 2012b).

Figure 4 shows examples of experimental and numerical results related to flow behavior of natural air convection and heat transfer from the heated plate. For numerical simulation CFD program with six different turbulence models were applied. It is seen that selection of turbulence models affects strongly numerical results. Further studies are required on turbulence modeling of flows under strong buoyancy effect. The test data achieved are well suitable for validation of CFD programs.

**Table 2** Test facilities at SJTU for containment cooling

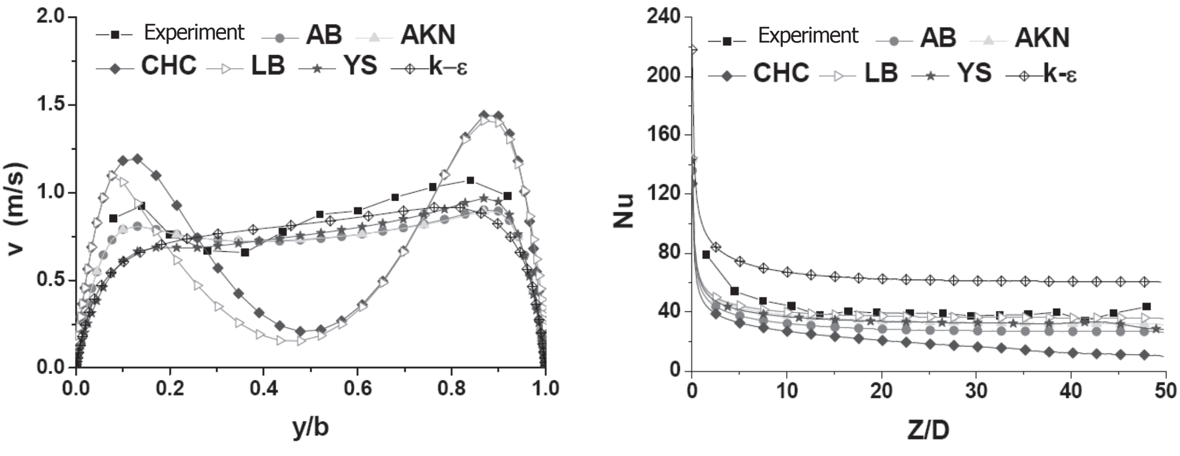
| Test facility | Main purposes |
|---|---|
| MICARE | Natural air convection heat removal capability and effect of thermal radiation heat transfer |
| WABREC | Water film behavior under isothermal conditions (film thickness, film velocity, coverage rate); Effect of various parameters, such as count current air flow, inclination, surface properties; |
| WAFCORE | Water film behavior and heat transfer under heat input: Boiling inside film; Effect of air flow; Engineering confirmation tests |



(A) Scheme of MICARE (b) Picture of MICARE

Source : Yu (2012a)

**Figure 3** Test facility MICARE




(a) velocity (b) heat transfer

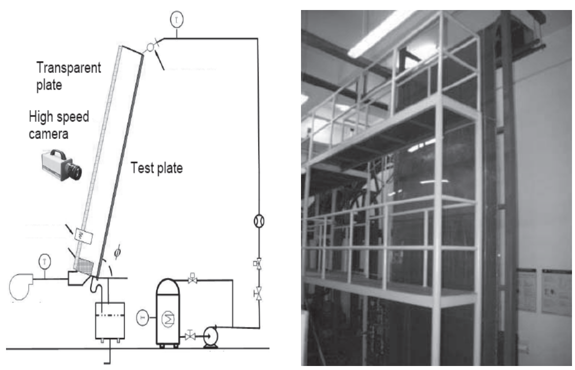
Source : Yu (2012a)

**Figure 4** Comparison of experimental data with numerical results using various turbulence models. AB, AKN, CHC, LB, YS and k-ε indicate six different turbulence models:

**(b) Water Film Behavior**

The test facility WABREC (Water Behavior in Rectangle Channel), as schematically illustrated in Figure 5, is devoted to study water film behavior, such as water film thickness, break and dynamics. It consists of two parts. In the top it is a one fourth cylindrical surface with 2m diameter, whereas the lower part is a straight plate of 2m width and 5 m length. The upper part is required to achieve an expected water film distribution at entering into the straight plate. Plate surface is pained with Carbozinc 11 HSN, the same material as used in AP1000. Capacitance probes are used to measure local film thickness. High speed camera is applied to visualize water film surface dynamics and to measure surface wave propagation velocity and water film coverage rate. An outer channel with transparent channel wall can be added to the test section to enable count current air flow conditions.

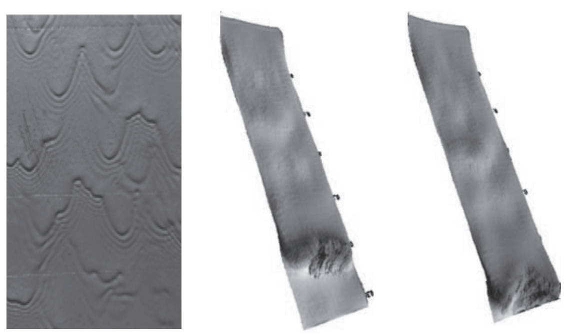
Figure 6 shows the water film surface and surface wave characteristics from both experimental observation (Figure 6a) and numerical simulation of CFD (Figure 6b & 6c). As seen, water film surface wave behavior can be reasonably simulated with CFD approach.




(a) Scheme of WAFREC (b) Photo of WAFREC

Source : Yu (2012b)

**Figure 5** Test facility WABREC



(a) Experimental observation (b) CFD results at t0 (c) CFD results at t0+0.05s

Source : Yu (2012a)

**Figure 6** Experimental and numerical results of film surface wave

Based on the present studies, a new correlation is proposed for the average film thickness:

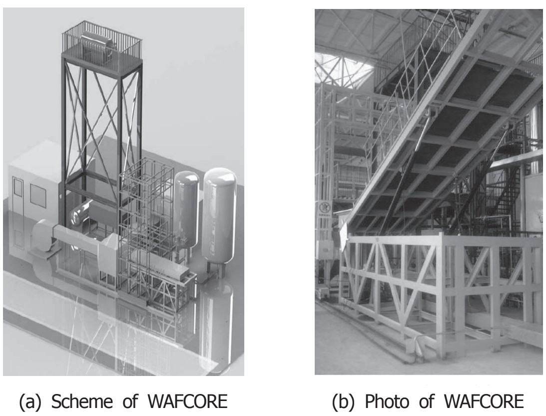
$$\overline{\delta} = 0.462\,\mathrm{Re}^{0.422}\left(\frac{\nu^2}{g\sin\phi}\right)^{1/3} \tag{1}$$

This equation is valid for water film Reynolds number range (80 < Re < 600).

**(c) Engineering Confirmation**

In addition to the two fundamental research facilities MICARE and WABREC, A large scale test facility WAFCORE (Water Film Cooling in Rectangular channel) was recently constructed, to investigate water film performance under prototypical conditions.

The WAFCORE facility, as shown in Figure 7, consists of a plate made of stainless steel with a dimension of 5 m x 1.2 m. The plate surface is painted with organic zinc to maintain good wettability. The plate is heated by high temperature oil from back side. A visualization window is mounted parallel to the stainless steel plate, about 5~30 cm apart from it, to form a rectangular channel simulating the air gap existing between the containment steel vessel and the baffle in the reference design. A blower located at the bottom of the channel, circulates air flowing into the rectangular channel with velocity up to 15 m/s. Heat flux at the plate surface could be varied up to 100 kW/m2. In addition to previous fundamental studies, two additional phenomena will be investigated at the WAFCORE facility, i.e. water film behavior under heat input and boiling phenomena and heat transfer inside water film.



(a) Scheme of WAFCORE (b) Photo of WAFCORE

Source : Hu (2012)

**Figure 7** Test facility WAFCORE

### 3.2 IVR Related Phenomena

During the transient phase of severe accident (SA) progression, integrity of reactor pressure vessel (RPV) lower head is threatened by a wide spectrum of phenomena, e.g. various melt relocation scenarios, potential steam explosion, jet impingement, etc. A limiting case and strategy in late phase of severe accident is maintenance of lower head integrity through external cooling of the RPV head to reach the in-vessel retention of molten pool (IVR-ERVC). Figure 8 shows schematically the principle of IVR and some key phenomena involved.

Under core melt accident, molten fuel and molten structural materials are collected in the lower head of RPV. Decay heat is released in the melt pool and needs to be removed via thermal radiation at the upper pool surface and conduction/convection to water at the outer surface of RPV. Inside core melt with high Rayleigh number, flow has features of strong turbulent mixed convection (Rempe et al., 2004; Rempe et al., 2005). The thermal-hydraulic behavior of the melt pool, and subsequently the heat flux at the RPV outer surface is dependent on melt pool structure, which is

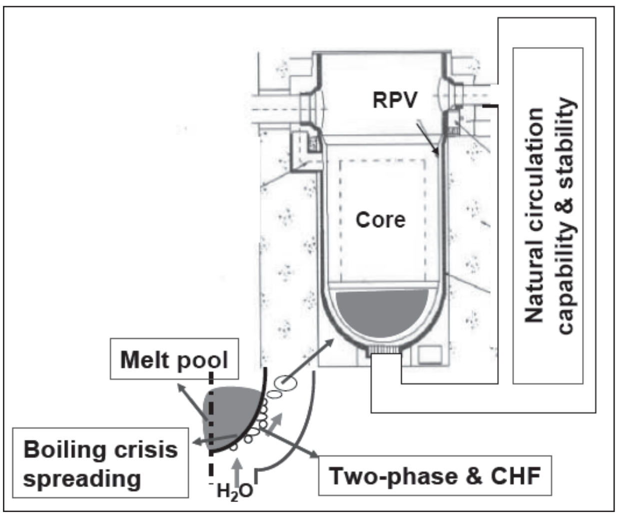



**Figure 8** Scheme of IVR principle

in spite of extensive studies still not well understood. Due to high heat flux, boiling occurs at the RPV outer surface and keeps the surface temperature slightly higher than the saturating temperature of water. The upper limit of heat transfer capability at the RPV outer surface is determined by the phenomenon "boiling crisis". In case no boiling crisis occurs, a sufficient heat removal and RPV cooling is assumed. As soon as boiling crisis occurs, the RPV outer surface temperature could sharply increase. In the nuclear community it is generally agreed that the occurrence of boiling crisis would directly lead to RPV failure. Therefore, efforts were mainly restricted to investigate critical heat flux and to measures enhancing critical heat flux. However, there is significant deficiency in understanding boiling crisis propagation and post CHF heat transfer.

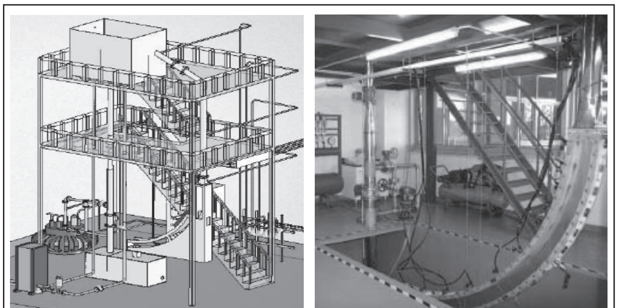
The IVR-ERVC concept was first investigated and explored for the Loviisa pressurized water reactor (PWR) in Finland. It was accepted as the major accident management measure by the Finnish regulatory agency. In the USA, the design of the advanced passive reactor AP-1000 employs ex-vessel flooding as an accident management scheme. The safety strategy of AP1000 is to keep RPV intact at any conditions, including severe accident core melt conditions. There is no core catch outside RPV. Late on, IVR-ERVC was also proposed for other PWRs and BWRs such as Korean APR-1400 (Rempe et al., 2005) and German SWR1000 (Stosic, 2008).

In China, IVR-ERVC concept has been adopted in the design of several advanced reactors, e.g. CPR1000 (Li et al., 2010). For extending the reactor power of AP1000 to higher level, the feasibility of the passive IVR-ERVC concept becomes one of the bottlenecking factors and attracts extremely strong attention of the Chinese nuclear community (Wang et al., 2012). Both experimental and theoretical studies were initiated at SJTU as early as 2008, in collaboration with Shanghai Nuclear Research and Design Institute and CGNPC. The IVR-ERVC project at SJTU consists of two parts. The first one is devoted to fundamental studies on phenomena involved in IVR-ERVC, whereas the second part concentrates on integral heat removal performance.

**(a) Fundamental Phenomena**

For fundamental studies, the test facility REPEC was built at SJTU and illustrated schematically in Figure 9. The REPEC test facility simulates ERVC with a full height loop and a slice geometry test section. Vapors are generated on the heating surface, mixed with water in the test section, vented through the upper tanker and released to the atmosphere. The configuration of the test section is a slice with the same radius of RPV lower head, and the width of which is 0.15m. To get a direct observation of the flow boiling phenomena, transparence glass windows are designed in the test section. The test section is heated by 27 individually controlled heating zones. The designed maximum heat flux approximates to 1.2MW/m2. The experimental study consists of two phases:

- Phase I. Cold tests: Air is injected from the vessel wall simulating vapor generation. The main purpose of the cold phase is to investigate two-phase flow characteristics such as flow regime, void fraction distribution and natural circulation capability.
- Phase II. Warm tests: Vessel wall is electrically heated and vapor is produced on the wall surface. The main purpose of the warm tests is to study heat transfer & CHF in the gap, thermal stratification and natural circulation instability.



(a) Scheme of REPEC (b) Test section of REPEC

Source : Li (2010)

**Figure 9** Test facility REPEC

**(b) Engineering Confirmation**

The second part of the IVR-ERVC program at SJTU is oriented on integral performance of IVR-ERVC. For this purpose the REPEC-II facility was constructed, as illustrated schematically in Figure 10.

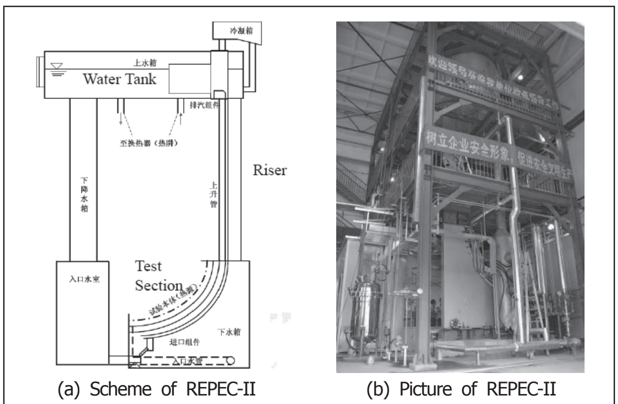
The main technical features of the REPEC-II test facility are summarized as below:

- Full height; total height about 12 m, same as in the design of CAP1400;
- Surface scale: 1/100;
- Various heat flux distribution simulating different accident scenarios;
- Comprehensive two-phase measurement, including visualization;
- Both forced and natural circulation possible;
- Maximum electric power supply: 1.1 MW, which gives a maximum surface heat flux up to 2.6 MW/m2.

The main objectives of this project are to investigate

- Two-phase flow and heat transfer performance in ERVC;
- Integral ERVC system performance, including natural circulation capability, flow stability;
- Critical heat flux under prototypical conditions, to provide engineering data supporting the license procedure of CAP1400;
- Effect of various parameters on ERVC capability and their optimization.

In addition to experimental work, numerical investigation using 1-dimensional system analysis program and 3-D CFD program was carried out to study the ERVC system performance and to support the test facility design. Figure 11 shows one example of the system analysis simulation presenting the boundary of flow stability of the CAP1400 ERVC system. As recognized, lower sub-cooling of water entering the RPV cooling channel or higher heat power reduces the stability margin. For a total decay heat of 25 MW, the present ERVC system shows instable behavior, as soon as the subcooling is lower than 15°C. The numerical results require experimental validation and if necessary, the ERVC system needs modification based on both experimental and numerical investigations, to enhance its flow stability.

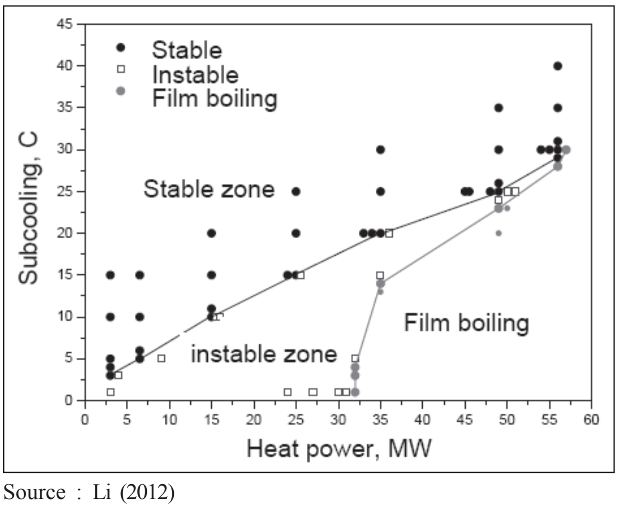



Source : Kuang (2012)

**Figure 10** Test facility REPEC-II

## 4. Summary

Development of environment friendly energy supplies becomes a crucial issue in the future Chinese economy. Due to the well-known limitation in renewable energy and hydro-power, nuclear power is considered as a safe, clean, sustainable, and economic energy source. The Chinese government issued an ambitious program of midterm and long-




Source : Li (2012)

**Figure 11** Calculated flow stability map of ERVC system term nuclear power development. Nuclear safety was well recognized having the top priority in the nuclear power development. Considering the Chinese specific situation, experience gathered in the national and international nuclear community and the importance of passive safety systems, AP technology of Westinghouse is accepted as one of the main technology line for the Chinese GEN-III PWR.

The Fukushima accident has strong impact on the nuclear power development in China, especially related to nuclear safety and severe accident mitigation. Directly after Fukushima accident, the State Council suspended approvals for new nuclear power plants and conduct comprehensive safety checks of all nuclear projects, including those under construction. The construction work of four approved units was also stopped and many projects underwent delays. Until October 2012, after issuing the Nuclear Safety Plan, approval of new plants was restarted. According to the "12th 5-year Plan for Nuclear Safety and Radioactive Pollution Prevention and Vision for 2020", compiled by the Ministry of Environment and approved by the State Council, China will spend RMB 80 billion to improve nuclear safety of nuclear power plants at operating and under construction over the next three years.

A large number research and development (R&D) projects was launched and are proposed in recent years related to nuclear safety and severe accident mitigation. In the frame of the "National Large Scale Project", which is coordinated by the State Nuclear Power Technology Corporation, research activities were initiated, which cover various aspects of severe accident prevention and mitigation. Numerous test facilities and research infrastructure were established or under construction.

Directly after Fukushima accident, the National Energy Administration initiated and financed research projects, in direct connection with Fukushima accident. In the newly issued Nuclear Safety Plan, R&D in nuclear safety and severe accident prevention and mitigation is a main topic with two different targets. The first target is devoted to the construction of research capability and infrastructure, whereas the second target to scientific tasks covering more than 100 individual subprojects.

In addition to the projects financed by Chinese central government, many research activities are also ongoing at nuclear industries and research institutions financed by nuclear industries or local governments. All these form a large community of nuclear safety research. At the same time, this community is making big efforts in enhancing international exchange and collaboration. In April 2008, the International Workshop on Passive Safety System (IPASS08) was organized in Shanghai, and in September 2012, International Workshop on Nuclear Safety and Severe Accident (NUSSA) was held in Beijing with more than 150 participants from more than 10 countries.

In the last few years the nuclear safety research community has been growing rapidly. It consists of nuclear industries, research centers and universities. The Shanghai Jiao Tong University has been actively working on nuclear safety research since more than 10 years, engaged in various aspects such as IVR-ERVC, PCCS, fuel-coolant interaction and hydrogen safety, and becomes now one of the key institutions in this community. Many test facilities for both fundamental research and engineering confirmation established. The main features of the R&D works at SJTU are:

- In tight collaboration with nuclear industries;
- Fundamental research combined with engineering applications;
- Experimental investigation accompanied with extensive theoretical and numerical studies;
- Open for international collaboration.

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# Book Reviews

**Knowledge, Policy and Power in International Development : A Practical Guide, Harry Jones, Nicola Jones, Louise Shaxson, and David Walker, The Policy Press (2012), ISBN: 978-1447300953**

*Introduction*

In the Asian region, there are some countries such as Korea and China that have successfully caught up with the advanced economies in only a short span of time. The policies, which have underpinned such growth, have historical value as the data for sustainable growth in the future and they become the objects of analysis for national development policies of other countries in Asia.

In spite of the rapid growth of some Asian countries, many countries in Asia in general have short history of national innovation policies because industrialization in Asia started later than the West. It means that their experiences—obtained from the knowledge of various innovation policies or through the implementation of those innovation policies—have not been sufficiently accumulated in comparison with the West. Therefore, it would be difficult for these countries attempting to adopt a successful innovation policy of other nations to predict whether they can manage to introduce the policy to their counties properly or whether the adopted policy would work as expected.

Taking these into consideration, this book will be very useful for the readers interested in innovation policies in Asia because it can provide in-depth understanding on the complexity that occurs in the actual process of policy making. Specifically, this book describes the various actors associated with knowledge-policy interface and the power dynamics among different intellectuals, suggesting a practical guide to practitioners as well as researchers. The scholars who study the innovation policies tend to ideally think that they can derive the desired effects by applying their knowledge on innovation policy immediately to the policies. However, this book provides thematic description on very diverse social interactions surrounding policy-related knowledge until it is reborn as an actual policy. It would also help the readers get the macroscopic perspective on the whole process in which the innovation policy of a nation can take the real effect after starting from the knowledge production stage.

*Main Contents*

Except for Chapter 1, the introductory part, and Chapter 6, the description of conclusion and implications, this book introduces the four main elements that influence the knowledge-policy interface in each of the different chapter one by one.

In Chapter 1, the importance of the subject, “the link between knowledge, policy and power in development”, dealt with in this book and the backgrounds of the discussion are first explained. Furthermore, this chapter helps the readers prepare for the abstract concepts that will be used in future logical development by briefly suggesting the definition of key words used in this book, such as policy, knowledge, and knowledge-policy interface, etc.

In Chapter 2, the political context is introduced as the first element that influences the knowledge-policy. The authors reject the simplification of the policy making process into a mere phrase, such as “it all depends on political will”, and analytically explain how the political context can influence the knowledge-policy interface. As political context, this chapter suggests various elements, such as restraints on power (separation of powers), decentralisation, regulation and competitiveness of political participation, informal politics, external forces, and the capacity to absorb change. Furthermore, it classifies the political form of a nation into more consolidated democracies, more autocratic governance, more fragile or postconflict states. Then it explains what particular significance the various forms that define the political context have in each different political forms. The various cases introduced in the process of introducing various elements defining the political context help the readers understand the key points, not making them immerse only in complicated and abstract concepts.

Chapter 3 introduces various actors who connect the knowledge-policy interface. It also explains how those various actors make decisions in their activities of knowledge production, delivery, and application, and how they ultimately influence the knowledge-policy interface. The authors comprehensively accept the trend of other previous researches, such as the rational choice theory, pluralism, Marxist theory, and researches that stress the roles and functions of institutions. Previous researches were focused on the bureaucratic and academic researchers as the main actors. In this book, however, the discussions are conducted on much wider concept that covers very diverse actors in the categories of the policy actors, knowledge actors, and intermediaries. In the first part of this chapter, three elements, such as actors' interest, actors' beliefs and values, and actors' credibility are suggested as a theoretical ground that can comprehensively explain the behavior of those various actors. In the last part of this chapter, the tools for the readers, who should negotiate with others in response to the behavioral characteristics of those various actors, are suggested.

In Chapter 4, the kinds of knowledge to be used in policy making process in knowledge-policy interface are classified and explained. The authors are classifying the knowledge into three categories: research-based knowledge, practice-informed knowledge, and citizen knowledge. This chapter first gives clear definition on what exactly each of these three categories stands for. It also provides deep analysis on how different is the knowledge in each of those three categories according to major issues, such as actors, source of knowledge, and knowledge flow that occur when the knowledge is used for policy making. The middle part of this chapter explains what kind of power dynamics occurs in the process of each different kind of knowledge being connected with the relevant policy. In the last part of this chapter, practical implications are provided on how those different kinds of knowledge can be utilized in policy making.

Through the contents from Chapter 2 to Chapter 4, the authors of this book argued that the process of policy making is not one of those linear and sequential processes, such as conception, implementation, and monitoring and evaluation process. Consequently, it appears that these chapters are trying to explain that the complex process of different kinds of knowledge interacting among various actors is the essence of knowledge-policy interface. Chapter 5 deals with the role of intermediaries, which are the media of knowledge interaction among various actors. The authors are systematically delivering the various roles of intermediaries in knowledge-policy interface through the six functions performed by intermediaries. These six functions are informing, linking, matchmaking, engaging, collaborating, and building adaptive capacity. By describing the characteristics of detailed items, such as definition, strength, and weakness, this chapter gives the clear introduction of relevant functions. In the last part of this chapter, practical guide is suggested on how the function of such various knowledge intermediaries can be used in knowledge interaction. The authors of this book insist that the knowledge interactions be performed through the intermediaries in each stage of "undertaking a needs assessment" (step 1), "understanding organisational mandates" (step 2), "sequencing the choice of intermediary functions" (step 3), and "interpreting the results and monitoring process" (step 4).

In Chapter 6, the last chapter, the authors are suggesting political implications while concluding the discussion on knowledge-policy interface. In particular, they wrap up the book by separately describing implications of their analysis for knowledge producers, knowledge users, knowledge intermediaries, and donors.

*Concluding Remarks*

While introducing the knowledge-policy interface, this book not only covers the comprehensive range of political economy so that it can be adopted by various countries, but it also secures the generality that can be applied to different policy areas. Accordingly, the readers interested in innovation policies of Asia will be able to use the contents of this book considering the different characteristics of each country, such as the kinds of actors that usually intervene in the political context or the process of policy making.

Considering that many papers in ARP Journal are producing new knowledge related to innovation policies, the understanding on the knowledge-policy interface introduced in this book is expected to play the role of helping the new knowledge to be actually reflected in the policies. It is also expected to contribute to the development of innovation policies of Asia by fostering complementary interaction with the research papers in ARP Journal.

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## Ecology of Wisdom, Arne Naess, Alan Drengson and Bill Devall, Counterpoint (2010), ISBN: 978-1-58243-592-3

The Norwegian Arne Naess who died in 2009 was philosopher, a mountaineer, an environment advocate, and a activist. He is also frequently said to be a person who marked a new era in the history of environmental movements in the 20th century, probably because *his Long-range Deep Ecology Movement* has large effects on environmental movements. Although he thought actions are important, he was a peace-loving person, who was never violent or radical. He has great respect for Gandhi. The book *Ecology of Wisdom* to be introduced now is an Anthology edited by Alan Drengson and Bill Devall containing diverse writings related to the *Long-range Deep Ecology Movement* written by Arne Naess.

One of the reasons I decided to introduce this book is the people's misunderstanding or misusing of the ecological terminology. I think that a few politicians and public officials sometimes tend to mislead or ignore philosophical elements inherent in ecology, that is, the philosophical elements of ecology, which are close to naturalism and reciprocity, although they talk about "symbiosis", "ecology", "ecosystem", and so on. There are some cases of misunderstanding and misusing the scientific terminology such as "evolution" and "evolutionary theory"; the evolutionary theory was sometimes misled as supporting eugenics or racism. Furthermore, without any consideration on the fundamental meaning of its own, the word "evolution" is used sometimes where the word "change" is sufficient, for the only reason that evolution is better expression. On reviewing recent use of terms related to ecology, I feel that this tendency is being intensified (as a recent example, ecosystemic development). Another reason for the selection of this book is that I think ecological concern should be included in policies for science and technology, including environmental technology. One of the roles of science and technology emphasized by the new Korean administration is to solve diverse social and welfare problems of people aside from economic problems. Therefore, reviewing the roles of humans and views of the world presented in *Long-range Deep Ecology Movement* will provide a moment to agonize over the direction for development and scientific technology to scientists or science and technology policy decision makers.

In the preface, the editors said, "... You may never have heard the phrase *Long-range Deep Ecology Movement*, but you might be a supporter of the movement and are awakening to your intuition of deep ecology." This probably means that the "*Deep Ecology*" concept has been recognized by everybody to some extent in mind and that most people are aware of the limitation of existing human-oriented conventional social development. The *Deep Ecology* makes people recognize "equality" and "the dignity of all lives", which are among the virtues that human should possess, the so-called "the lord of creation". Arne Naess is said to have considered himself as a teacher who taught individuals to clearly express their ecological wisdom (ecosophy) rather than a scientific philosopher. This book was made not to assert a unified ecosophy but to inspire readers so that diverse types of ecosophy owned by individual readers can be expressed—the very same ideology that Arne Naess pursued.

Ecosophy is a compound word made from "oikos", which means household (or house), and "sophia", which means wisdom. Therefore, if it is literally interpreted, it can be said to be "wisdom of living". To understand the meaning more concretely, please think about the meanings of "ecology" and "economy" that use the same root as "ecosophy".[1) ]It seems like some philosophers give a great meaning to "ecosophy" and comment on it positively or critically. In a writing that was done in his later years, Arne Naess referred to ecosophy T. (ecosophy Tvergastein; Arne Naess' own ecosophy). He state that everybody was not required to agree to ecosophy T., but just wanted everybody to realize the way to develop his/her own ecosophy through it. Of course, he mentioned thereafter that for "ecosophy" to become a philosophical basis that would accept the principle of deep ecology, it should be developed into a wider view of the world, that is, a philosophical view of the world (or system) that well reflects the conditions of living in the earth's ecosphere. However, given his view that basically acknowledges diversity, it is considered that he did not want for his ecosophy T. to be established as a dominant philosophy.

The *Ecology of Wisdom* consists of a preface, an introduction, and five sections containing 28 essays. In the preface, the background of the planning of this book and the editors' purposes are explained. The introduction ("The Life and Work of Arne Naess: An Appreciative Overview by Alan Drengson") is divided into two parts. The first part casts light upon Arne Naess' life. Here, we will see how much he is respected in Norway, the background of his concentrated attention to environmental issues, and the motive for him to have come to propose ecosophy and deep ecology movements. The second part is filled with explanations about the deep ecology and shallow ecology presented by him. Make sure to read this part because this contains brief and important explanations that are helpful in understanding ecosophy.

Section 1 "Places in the Real World" contains essays that explain Arne Naess' view of the importance of "places" in the base of the ecosophy possessed by each person. Everybody should have at least a place that comes to his/her mind when he/she recalls nature, ecology, living in nature, etc. In my case, a neat island in a forest comes to my mind. To Arne Naess, Tvergastein is such a "place". This place is located at an altitude of approximately 1,500 m in the southeast slope of Hallingskarvet, a mountainous region in Norway. It is said that Arne Naess built a cabin in this place sometime in 1937 and used the cabin as a place for philosophical thinking and writing activities. He learned the true interrelation between nature and humans and humility to nature and clarified his enlightenment into philosophical principles. In that he found "philosophical enlightenment" while living a lonely life in a secluded place as such, an aspect similar to the Oriental thought "Lao Tzu" or "Taoism" can be seen. However, rather than the foregoing, it can be thought that he could make clear judgments and could establish criteria for the judgments through deep contemplation. This section points out the fact that, by reviewing nature that surrounds them, people can perceive the interrelations between them and other living things and in the places where they are. It also points out the fact that we can know deeply about ourselves only through our personal questions. It also informs that because everything we know always changes, questions can be said to be something that always exist in our daily lives and that to creatively adapt to the unceasingly changing surrounding environments. We should not stop learning and we

1) Ecology = "oikos" + "logos"(study), Economy = "oikos" + "monos"(custom or law)

should contemplate things through deep meditation.

In section 2 "*The Long-range Deep Ecology Movement*", the deep ecology presented by Arne Naess is mentioned in earnest. Arne Naess seems to have thought that deep ecology movements should include three major elements: peace, social justice, and ecological sustainability. In that he emphasized social justice, Arne Naess may be judged to be a philosopher who regarded actions to be important. This section emphasizes the importance of diversity, cooperation, and beautiful actions. Along with the foregoing, this section points out the fact that a high level "pleasant life" is based on nonviolence and low consumption.

Section 3 "Methodology and System" focuses on Arne's approaches to global viewpoints, methodologies, pluralism, intensity, and creativity as methods to help the clarification of our ecosophy. It also explains about the role of creativity in our lifestyles and Naess'gestalt ontology.

Section 4 "Nonviolence and Gandhi, Spinoza and Wholeness" contains Gandhi's approach to group conflict. As is well-known, Gandhi's nonviolent resistance is a new form of civic movement, a way followed by many activists. In this section, Arne Naess explains why Gandhi's method is important to those who pursue cultural transformations in the 21$^{st}$ century. This section also contains essays on Spinoza that studied Spinoza's approaches to the philosophy of life.

Section 5 "Problems and Ways Forward" begins with an assumption that for several decades, at the start of the 21$^{st}$ century, society and culture have been facing huge personal, social, and environmental problems. Arne Naess presents conceptual frames for solutions of and approaches to these problems. Emphasizing that the effects of the frames may be determined by our nonviolence, he emphasizes that all living things and societies should form cooperative relationships in order to solve diverse problems to be placed (or already placed) in front of us. This section is particularly recommendable for scientists and policy decision makers to review without fail. In this section, we can clearly know the author's view of sustainability. Naess expresses unecological consequences of policies as follows;

$$\sum U = (\sum Pu + \sum Cu) \times N \tag{1}$$

That is, unecological consequences of policies are expressed by values obtained by multiplying the sum of unecological production and unecological consumption by the number of human population. From here, it can be seen that for sustainable development, not only the way of production but also the way of consumption should be changed to be ecological. Therefore, we should contemplate whether our current science and technology policies focus on only the development of the way of production. Naess' essay contained in this section explains the concept of sustainable development as follows.

"There is sustainable development if, and only if, it meets the *vital needs* of the present-day human population without compromising the ability of future generations to meet their own *vital needs*."

Comparing this definition with the definition in the Brundtland Report, he emphasizes that although the definitions are almost the same, the needs he referred to are not "simple needs" but "vital needs (for life)". That is, he indicates that although the list of simple "needs" may include many elements that are necessary but are not vital to the maintenance of life, by limiting the list to vital needs, the scope of needs can be reduced and the benefits of sustainable development can be distributed to more people.

As this is the case in many countries, including Korea, there is a tendency to think sustainable development as sustainable economic progress. Naess showed concern about this viewpoint and pointed out that this viewpoint might be against the aforementioned definition. He argued that ecological sustainability was vital to sustainable development and that global and local biological diversity should be sufficiently guaranteed to maximize ecological sustainability. The editors decorated the end of this section with an essay entitled *Deep Ecology for the Twenty-Second Century*. Through this essay, Arne Naess showed the fact than human society wanted to go toward wider and more comprehensive sustainability rather than the narrow economic sustainability, expecting better future through it. Arne Naess considers sustainability as an important element for the future to the extent that he expressed it as an indispensable approach.

Sustainability, pushed back to a lower priority than green growth, looks like taking back its original position in present administration. Although the fact that sustainable growth was emphasized rather than development is somewhat regretful and worrisome, present government's careful consideration about sustainability is much encouraging. Reviewing Arne Naess' view of deep ecology at this time is considered to be an opportunity to look at policies from new viewpoints. It should be certainly helpful in conceiving policies that would affect longer temporal ranges than policies for 5–10years. Finally, I would like to finish this book review with part of Arne Naess' writing, which is common but touches my heart.

*" ... confident that we have a mission, however modest, in shaping a better future that is not remote. Just a couple of hundred years."*

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## Propensity Score Analysis: Statistical Methods and Applications, Shenyang Guo and Mark W. Fraser, SAGE Publications, Inc. (2009), ISBN: 978-1412953566

This book, written by Guo and Fraser, deals with the statistical (or econometric) methods used in quantitative evaluation of a treatment. Specifically, this book focuses on explaining the method of propensity score analysis, which has been used in many fields for the last 10 years. The methodology was developed to solve the selection bias problem, a major issue that occurs in performing evaluations. Propensity score analysis was first used to watch the effect of medication or treatment in the health and medical statistic fields. However, the range of its application has become wider and wider to include areas, such as governmental policy evaluation, etc.

Take the evaluation of the effect of a newly developed medicine for example. First, you will need a medication group and a comparison group. By comparing the two groups with the change in time, you will see the effect of the newly developed medicine. When you experiment with white rats, you can give the test drugs to rats that are randomly selected with no feeling of guilt and leave the other rats as they are to see the effect of the newly developed medicine after a few months. If the number of the rats is sufficiently enough, you can also obtain the statistical significance of the quantitative evaluation effect. This is the randomized experiment, which is a basis of scientific experiments that uses experiment and comparison groups. However, if you try to create an experiment group and comparison group of actual people through random selection, you may be faced with economic and ethical problems. After all, people get medicine because they want to be cured of their diseases or because they show symptoms of a disease. Patients often have physical conditions different from other normal people in many aspects. Accordingly, the method of measuring the effect of a medicine through simple comparison of medication group with normal people group after lapse of a certain period of time can have statistical bias in its results. This bias, which occurs because the characteristics of the experiment group that receives some treatment are different from those of the comparison group, is called selection bias.

The above problem can arise in the evaluation of various fields of different targets and different perspectives. Take the example of a labor policy that carries out job training for the unemployed. The attempt to evaluate the effect of the labor policy through simple comparison of future employment rate of the group of people who received the job training with that of the group of people who did not receive the job training can cause the problem of selection bias. This is because the government, with limited financial resources, would not randomly select people but deliberately select and train people who have high possibility being employed in the future.

Otherwise, the government would be faced with the criticism that it wastes or it does not efficiently use its financial resources. In a wider scope, the problem of this selection bias can occur in the evaluation of an educational policy, a labor policy, and an firm-level policy, such as venture subsidy, microfinance, and R&D support, and even in the analysis of local government policies at the city and provincial levels and in comparative evaluation of trade and regulation policies at the national level as well.

As the controlled randomized experiment cannot be performed in the social science field, the problem of selection bias is likely to occur in the evaluation of the effect of treatment on a certain group of participant. Solving the problem of selection bias has been a great task to statisticians or econometricians. The propensity score analysis introduced in this book was developed in the early part of the 1980s by the contribution of Rosenbaum and Rubin, who were the statisticians, and by Heckman, who was an econometrician. In particular, Heckman won the Nobel Prize in economics in 2000 in recognition of his contribution to the development of various methods to deal with this selection bias. The purpose of propensity score analysis is to create similar conditions as the randomized experiment, if it is impossible to perform the experiment—the index of propensity analysis, which means the probability of participating in certain treatment—plays an important role. In other words, if there is sufficient information on the experiment group that participates in the treatment and on the comparison group, and if the selection process is known, the propensity score can be estimated. The statisticians found out, under several strong assumptions, that the new experiment group and the comparison group with possible randomized experiment can be created in matched pairs of participants and nonparticipants with similar propensity scores. This became the basic idea of various propensity score analyses.

This book is composed of the following chapters. Chapter 1, the introductory part, describes on the advantages of the randomized experiment and problems, such as the selection bias that can occur when the randomized experiment is impossible. It also introduces the concept of propensity score analysis and its application cases in various fields, such as evaluation of education, labor, medical, and health policies as well. Furthermore, this chapter also introduced the procedures developed by many researchers in order to perform the propensity score analysis in statistical programs, which are frequently used, such as SAS, STATA, and R.

Chapter 2 introduces the four methods that are the major subjects of this book, such as Heckman's Sample Selection Model, the Propensity Score Matching Model, Matching Estimators, and the Propensity Score Analysis with Nonparametric Regression, and the assumptions they share.

Chapter 3 deals with data balancing. Data balancing is an attempt to get similar effects as randomized experiment by adjusting the experiment group and the comparison group in various observation data dealt with in the evaluation of social science field. This chapter introduced the methods of data balancing that are frequently used, such as OLS regression, matching, and stratification, and described on their pros and cons as well.

Chapter 4 mainly describes the sample selection model of Heckman and the characteristics of samples that are applicable (or inapplicable) case of the model. In particular, this chapter introduces the instructions and exercises of STATA program that can implement Heckman model, describing in detail their respective pros and cons as well.

Chapter 5 is considered the most important chapter of this book. This chapter explains why the Propensity Score Model is a useful evaluation tool in comparison with various methods described in previous chapters. In particular, this chapter introduces the methods of various data balancing used in actual analysis, showing on the process flowchart in selecting the method to be used according to the purpose and sample characteristic. Furthermore, this chapter shows the pros and cons of each method by using STATA and R.

Chapter 6, which continues from Chapter 5, introduces various attempts to obtain the significance of quantitative evaluation of a treatment that was analyzed using propensity score analysis. Propensity score analysis has semiparametric or nonparametric nature that makes it difficult to derive statistical significance using the conventional methods. Statistical research efforts have been concentrated in this area for the last few years, and the authors of this book introduce recent research results of the frontier research groups.

Chapter 7 deals with the nonparametric regression, which is another analysis method using propensity score, and Chapter 8 describes on the method of performing the sensitivity analysis to check the robustness of the analysis results.

Lastly, Chapter 9 explains 18 kinds of mistakes that are frequently committed in using the propensity score analysis, summarizing the criticisms on the effectiveness and reliability of the methodology itself and the future developmental directions as well.

Recently, the government is actively making efforts for efficient policy implementation and accurate quantitative ex-post evaluation of the policy lies at the center of this change. The same is true of the governmental support to R&D. Due to its uncertainty, large variation in the result of each project, and spill-over effect, R&D is known to be an area where it is difficult to carry out policy evaluation. Recently, however, European countries are attempting to quantitatively evaluate the effects of governmental supports for various R&D projects using the data accumulated from the surveys (such as the Oslo manual). The methods that are frequently used in this evaluation are Heckman's selection model or various propensity score analysis introduced in this book. Those interested in policy evaluation will be able to obtain enormous tips from this book about the overall subjects covering the pros and cons of various methods, the selection of proper methods according to the evaluation purpose and samples, and the actual analysis in using the statistical program. However, the most important value of this book may be lying in the final conclusion. The authors of this book are points out the improper use of propensity score analysis in its frequent application recently, where a checklist of 18 patterns of mistakes was shown. Actually, the propensity score analysis requires vast amount of data from the policy (or treatment) participants and nonparticipants. Furthermore, these data should be able to reflect the selection process well. Above all, considerable number of participants is required to observe the significant result because this is a statistical method. Recently, there are many cases where propensity score analysis is applied in actual evaluation of governmental support policy. Close examination of this checklist will be greatly helpful in getting more robust results.

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Science and Technology Trends

# Open Innovation Policies in Asian Countries

JinHyo Joseph Yun[1*], Woo Young Jung[1**]

**Abstract**
The present paper summarized open innovation policies of three countries—Korea, Japan, and China—based on the frame of analysis of open innovation policies proposed by Chesbrough and Vanhaverbeke (2011), which centers specifically on recent policies used since the 2000s. Literature analyses were basically used and interviews were used in a limited range.
In particular, from the viewpoint of knowledge production, distribution, and consumption, open innovation policies of the three countries were summarized and their characteristics were briefly compared. In addition, Asian countries' several misunderstandings of open innovation were elucidated. Asian countries' several particular misunderstandings of open innovation in contrast with Western countries grasped in the processes of literature analyses, interview analyses, and this authors' study of open innovation were described. Finally, based on the comparison and analysis of the three countries' open innovation policies and the elucidation of Asian countries' several misunderstandings of open innovation, several open innovation policies for Asian countries were proposed.

**Keywords**: Open Innovation Policy, Asian Countries, Open Innovation, Arrow Information Paradox

## 1. Introduction

"Open innovation" means that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well (Chesbrough, 2003). This approach places external ideas and external paths to the market on the same level of importance as that reserved for internal ideas and paths to the market during the closed innovation era (Sridhar & Avinash, 2008). Eventually, open innovation means R&D without borders (Chesbrough, 2006).

Open innovation is a concept that integrates conceptually quite diverse present innovation and new economic phenomena. The sharing economy suggested by a group of economists, including Elinor Ostrom; the user innovation suggested by scholars, who use sociological approaches, such as Von Hippel; and "Wikinomics" suggested by Don Tapscottt and Anthony Williams and others are discussions presented on the other side of business administration to which open innovation is materially related. That is, all of sharing economy (Elinor, 1990) that takes notice of a new possibility of commons that may be achieved through negotiations or systems, Wikinomics (Tapscott & Williams, 2009) which is an economy based on many people's knowledge and technology surpassing individuals as with Wikipedia, and user innovation (Von Hippel, 2005), which is a phenomenon for individualized users' ideas and knowledge, are connected not only to existing products, but also to new product innovation in the times of knowledge-based economy, which surpassed industrial society, are different shapes of open innovation that are concretely

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realized through the utilization of knowledge and technology across the boundaries of enterprises.

The amount of knowledge has been explosively increasing to the extent that it is beyond the boundary of a certain business, country, or cluster and the speed of knowledge distribution has been increasing enormously based on the second IT revolution, no matter whether it is coded knowledge or tacit knowledge. As a result, the amount of knowledge and technology faced by an individual business, a certain cluster, or an individual country has become much larger than those produced by them (Yun & Mohan, 2012). Therefore, not only at the level of a country or a certain cluster, but also at the level of an individual business that efficient open innovation policies and strategies have become essential elements for the growth and development of the relevant country, cluster, or business. Therefore, as with open innovation strategies at the level of a business, which are essential for the growth and development of the relevant business, a certain country's open innovation policies are also very important for the relevant country's economic growth and development.

Open innovation policies refer to a series of policies implemented by a certain country in order to promote the open innovation of enterprises in that country that activate the production, distribution, and consumption of knowledge and technology across the boundaries of enterprises in that country, such as technology transfer policies, industry-academic-research cooperation promotion policies, technology transaction activation policies, and technology-mediating intermediary activation policies. Open innovation policies are under a concept of a new form of policies that goes beyond the scope of existing industrial policies, technology policies, or research and development policies. The present study was intended to define the scope of open innovation policies at the level of hypotheses and summarize open innovation policies of major Asian countries, in particular, those of Korea, Japan, and China, within this conceptual frame. Due to limited time and limitations in research resources, in the present paper, the characteristics of open innovation policies of major Asian countries were summarized through literature analyses. However, to grasp concrete reality of open innovation policies, from February 4 to 8, 2013, in-depth interviews were conducted with one related section manager of the Ministry of Education, Science and Technology of Korea, one related section manager of the Ministry of Knowledge Economy of Korea, one related section manager of the Presidential Council for Science and Technology, one related section manager of the Ministry of Strategy and Finance, and one related section manager of the Office of National Tax Administration for one to three hours each. In addition, during the same period, an interview was conducted with the councilor in charge of scientific technology at the Embassy of Japan in Korea and literature data on the newest trend of open innovation policies of Japan were received. In the same period, an interview with a person related to the Embassy of the People's Republic of China in Korea was attempted but the attempt failed. Therefore, situations in related sites in relation to the newest trend of open innovation policies of China were grasped through interviews with a responsible section manager of the Ministry of Education, Science and Technology of Korea dispatched to the Embassy of the Republic of Korea in the People's Republic of China and a researcher in the Science and Technology Policy Institute.

Next, several misunderstandings about open innovation strategies or policies by persons in charge of policies in Korea or in many Asian countries that this author has come to recognize in the process of reviewing Asian countries' open innovation policies or in the process of studies of open innovation were elucidated. Finally, the present paper is finishes with a proposal of directions of policies and strategies for the activation of open innovation in Asia.

## 2. Boundary of Open Innovation Policy

Open innovation policies are intended to promote production, distribution, and consumption of knowledge and technology across the boundaries of enterprises in the country and have different characteristics from those of existing industrial policies, scientific technology policies, and research and development policies. First, let us examine the differences between industrial policies and open innovation policies. Industrial policies are diverse policies intended to promote the development of certain industries, which range from conventional industrial policies that correct market failure related to certain policies to activate the relevant industries to Schumpeterian industrial innovation policies that activate the innovation systems of the relevant industries to lead to enterprises' product innovation or process innovation. Open innovation policies are different from existing industrial policies in that they do not predefine industries or products per se and that they promote the production and distribution of protected knowledge as well as protectable knowledge instead of a certain sector.

Second, scientific technology policies focus on the activation of science bases in the country and the production of economically valuable technologies. Therefore, for the production of scientific and source technologies mainly by universities and the production of applied and developed technologies by government-funded research institutes or enterprises, not only the Ministry of Education, Science and Technology of Korea, but also almost all governmental departments become main agents of scientific technology policies, including individual departments in certain areas and the Ministry of Knowledge Economy focusing on applied and developed technologies. However, open innovation policies consider the distribution and consumption of knowledge and technology as importantly as the production of knowledge.

Third, research and development policies refer to various kinds of policies related to research and development investments necessary for the production of basic scientific and source technologies as well as various kinds of necessary applied technologies. That is, research and development policies focus on primary production of knowledge.

On the other hand, since open innovation policies aim at the promotion of the production, distribution, and consumption of knowledge across the boundaries of enterprises, encouraging enterprises to be equipped with the research and development capacities necessary for them to actively serve those functions as knowledge brokers in their areas should be included in important subjects of the policies.

Industrial innovation processes are becoming more open. The large, vertically integrated R&D laboratory system of the 20th century are giving way to more vertically disintegrated networks of innovation that connect numerous companies into ecosystems (Chesbrough & Vanhaverbeke, 2011). Based on the above discussion, the categories of open innovation policies are concretely presented in Table 1.

Open innovation policies are characterized by the fact that they focus on knowledge distribution and consumption in order to promote human and technology transfer and business start-ups based on the relevant technologies. In addition, knowledge production should definitely be included in concrete contents of open innovation policies, provided that, knowledge production policies, bearing knowledge distribution in mind, should be noticed in open innovation policies.

## 3. Review of Open Innovation Policy from Korea, Japan, and China.

### *3.1 Open Innovation Trends and Policies in Korea*

First, in sectors of education and human capital development, in particular, the aspect of the mobility of researchers is mainly reviewed. As shown in Table 2, in the case of Korea, basically, manpower exchanges between university-/government-funded research institutes and enterprises are remarkably less frequent compared to those between university-/government-funded research institutes and other research institutes or universities. That is, currently, in Korea, compared to researcher circulation between universities and research institutes—between knowledge-creating organizations—researcher transfer between knowledge-creating organizations (universities and research institutes) and knowledge-utilizing-and-consuming organizations (enterprises) is quite limited

To examine the present state of researcher transfer from universities to enterprises, not only transfers, such as dispatch and employment/leave of absence, but also researcher transfers in research years that do not affect research institutes' manpower operation are shown to be rare. The reason for this is said to be that

**Table 1** Concrete contents of open innovation policies

| Concrete Contents of Open Innovation Presented by Chesbrough and Vanhaverbeke | Nature of the Relevant Policies, Knowledge Production, Distribution, or Consuming |
|---|---|
| 1. Education and human capital development | |
| - increase meritocracy in research funding in the boundary | - production + distribution |
| - support the mobility of researchers among university, national laboratory, and companies | - distribution |
| 2. Financing open innovation: the funding chain | |
| - increase the pool of funds available for VC investment. | - consuming |
| - support the formation of university spin-offs to commercialize research discoveries | - distribution + consuming |
| 3. Adopt a balanced approach to intellectual property | |
| - reduce transaction costs for intellectual property | - distribution |
| - foster the growth of IP intermediaries. | - distribution + consuming |
| - rebalance university IP policies so broad diffusion of publicly funded research results is easier rather than focusing on royalty income alone. | - producing |
| 4. Promote cooperation and competition | |
| - shift support from national champion toward SMEs and start-up companies. | - distribution +consuming |
| - promote spin-offs from large companies and universities | - consuming |
| - focus on innovation networks | |
| 5. Expand open government | |
| - accelerate the publication of government data | - producing + distribution |
| - use open innovation processes in government procurement. | - producing + distribution |
| - support private commercialization of government-funded technology. | - distribution + consuming |

Source: Chesbrough & Vanhaverbeke, (2011). Partially revised

**Table 2** Present state of manpower exchanges between university-/government-funded research institutes and enterprises in Korea

(Unit: person)

| Type of exchange | Division of Organizations | Total | Research Institute | | University | | Business | |
|---|---|---|---|---|---|---|---|---|
| | | | Subtotal | Average | Subtotal | Average | Subtotal | Average |
| | Subtotal | 433 | 219 | 3.1 | 201 | 2.9 | 13 | 0.2 |
| Dispatch | Korea Research Council of Fundamental Science and Technology | 25 | 20 | 1.5 | 3 | 0.2 | 2 | 0.2 |
| | Korea Research Council for Industrial Science and Technology | 171 | 164 | 11.7 | 5 | 0.4 | 2 | 0.1 |
| | Research centered universities | 100 | 16 | 2.0 | 80 | 10.0 | 4 | 0.5 |
| | Industry-university collaboration project receiving universities | 137 | 19 | 0.5 | 113 | 3.2 | 5 | 0.1 |
| | Subtotal | 20 | 13 | 0.3 | 4 | 0.1 | 3 | - |
| Employment and leave of absence | Korea Research Council of Fundamental Science and Technology | 3 | 1 | 0.1 | - | - | 2 | 0.2 |
| | Korea Research Council for Industrial Science and Technology | - | - | - | - | - | - | - |
| | Research centered universities | 7 | 7 | 0.9 | - | - | - | - |
| | Industry-university collaboration project receiving universities | 10 | 5 | 0.1 | 4 | 0.1 | 1 | - |
| | Subtotal | 443 | 64 | 0.9 | 348 | 5.0 | 31 | 0.4 |
| Research year | Korea Research Council of Fundamental Science and Technology | 47 | 14 | 1.1 | 33 | 2.5 | - | - |
| | Korea Research Council for Industrial Science and Technology | 20 | 2 | 0.1 | 18 | 1.3 | - | - |
| | Research-centered universities | 142 | 30 | 3.8 | 106 | 13.3 | 6 | 0.8 |
| | Industry-university collaboration project receiving universities | 234 | 18 | 0.5 | 191 | 5.5 | 25 | 0.7 |

Source: National Science and Technology Commission (2012b).

incentives for working at enterprises are not sufficient to make researchers prefer working at enterprises to working at universities or research institutes. Next, to examine the present state of researcher transfers from government-funded research institutes to enterprises, although mid- to long-term transfers of experienced permanently employed researchers of government-funded research institutes are necessary to actually help enterprises, there are practical limitations due to regulations, such as prescribed numbers of employees. In other words, major reasons for inactive researcher transfers from government-funded research institutes to enterprises are government-funded research institutes' burdens for long-term transfers of permanently employed researchers due to limited prescribed numbers of employees and insufficient incentives for individual researchers.

In addition, incentives to attract researchers from enterprises to universities or government-funded research institutes are also insufficient. To conduct effective industry-academy-research institute joint research, not only researches of universities and government-funded research institutes should be transferred to enterprises, but also researchers of enterprises should be transferred to universities and government-funded research institutes with good research environments. However, although universities and government-funded research institutes have been supported with related facilities, such as business incubator centers, researchers for industry-academy-research institute joint researches have not been sufficiently secured. As of 2012, the Korean government has prepared diverse plans to activate researcher exchanges among industry, academy, and research institutes: these are the activation of transfers of university professors to enterprises using vacations and sabbaticals, plans to make dispatches of researchers of government-funded research institutes to small- and medium-sized enterprises substantial through giving incentives or separately operating prescribed numbers of permanent employees at the level of research institutes, and plans to install industry-academy-research institute joint research hubs in universities or government-funded research institutes to attract researchers of enterprises. On the other hand, universities have been reinforcing school-work links at the level of undergraduate studies by making contract departments and education programs that reflect market demands. In addition, universities have been successfully implementing policies to reinforce school-work links at the level of graduate school by making specialized graduate school systems centered on convergence technology for which the market requires specialized technologies. Nevertheless, the four subjects on in-depth interviews who are section managers of the Ministry of Knowledge Economy of Korea, the Presidential Council for Science and Technology, the Ministry of Education, Science and Technology of Korea, and the Ministry of Strategy and Finance commonly presented the insufficiency of researchers' fluidity among industry, academy, and research institutes as the most important problem that must be solved by open innovation policies of Korea.

Next, to adopt a balanced approach to intellectual property, the present state of the Korean government's policies for the distribution and consumption of knowledge and technology that would reduce transaction costs for intellectual properties is examined. Although diverse departments of the Korean government are operating diverse technology transfer information networks, as shown in Table 3, among others, no integrated online technology market at the level of the government has been systematically organized in Korea. That is, the diversity of information of NTB, which is a public technology integration network, is insufficient. For instance, NTB is just sharing some DBs with the Internet Patented Technology Mart under the Korean Intellectual Property Office that has the largest amount of information except for NTB on an annual interval. NTB shares only Meta information with information networks of departments other than the Korean Intellectual Property Office and thus integrated technology information searches are limited. As a result, there are considerable limitations for demanders to obtain desired technologies from NTB, which is an integrated site. Moreover, individual technology markets' information networks equipped with differentiated identities linked with related industries have not been activated either. Furthermore, the

**Table 3** Present state of technology transfer information networks operated by diverse departments of Korea

| Related department | Technology Transfer Information Network (year of establishment) | Operating Organization | Nature of Operating Organization | Number of DBs |
|---|---|---|---|---|
| Ministry for Food, Agriculture, Forestry and Fisheries (Rural Development Administration) | Outcome Yard (2010) | Korea Institute of Planning and Evaluation for Technology of Food, Agriculture, Forestry and Fisheries | Specialized research management organization | 464 |
| | Agricultural technology market place (2010) | Foundation of Agricultural Technology Commercialization and Transfer | Technology transacting organization | 1,397 |
| Defense Acquisition Program Administration | Private and military technology cooperation promotion center (Cyber technology exchange information yard, 2011) | Agency for Defense Development | National research institute | 739 |
| Ministry of Health and Welfare | Health Technology Transfer Center (2011) | Korea Health Industry Development Institute | Specialized research management organization | 506 |
| Ministry of Knowledge Economy | National Technology Business integrated information network (NTB, 1999) | Korea Institute for Advancement of Technology | Specialized research management organization | 91,343 |
| | Daedeok Innopolis Technology Commercialization Information System (DDIT, 2006) | Innopolis Foundation | Technology trust organization | 9,330 |
| Korean Intellectual Property Office | Internet Patented Technology Mart (IP-Mart, 1997) | Korea Invention Promotion Association | Technology transacting organization | 54,815 |
| Ministry of Environment | Korea National Environmental Technology Information Center (KONETIC, 2000) | Korea Environmental Industry and Technology Institute | Specialized research management organization | 396 |

Source: National Science and Technology Commission, (2012a).

information on supplied technologies presented by NTB and the Internet Patented Technology Mart is inclined to formality and thus important technologies are omitted or added information to support price determination for technology transactions is insufficient so that the usefulness of NTB and the Internet Patented Technology Mart is very low.

In addition, currently in Korea, the level of both online and offline technology brokerage markets for technology transfer is remarkably lower compared to the level of national research and development investments or universities and industries. This can be sufficiently identified from the fact that, in 2010, although national research and development tasks in which enterprises participated accounted for 48% of all national research and development tasks, the records of commercialization of those tasks were only 19% of the records commercialization of all national research and development tasks. The evidence can also be identified from the fact that the productivity of technology transfer per case (royalty/number of cases of transfer) of national research institutes in Korea country is very low to the extent that 1/17 of it is in the USA and 1/3 of it is in Europe. The biggest reasons for this are that market leading type enterprises or experts specialized in technology transfers are not activated in Korea. The infantility of technology-mediating industry in Korea can be estimated from the attitudes of the Korean research world and industrial world that regarded global technology-mediating enterprises, such as Intellectual Ventures and InnoCentive, as patent trolls when these technology-mediating enterprises entered Korea. In addition, currently, the share participation type technology transfer method that will enable universities or government-funded research institutes to receive a part of technology royalties as stocks instead of cash when they have transferred patents to enterprises is restricted, deactivating active technology transfers. Although approximately 160 organizations dedicated to technology transfers (Technology Liaison Office) were made by universities and government-funded research institutes in Korea in 2010 pursuant to the law, most of them are very small and have no base for self-reliance. In the case of Korea, not only linkages between the outcomes of national research and development projects and technology commercialization support projects are insufficient, but also systems to reflect market demand when planning national research and development projects have not been organized. The largest task of the Korean government's open innovation policies for enhancing the fluidity of knowledge and technology among industry, academy, and research institutes can be said to be eventually the activation of knowledge and technology-mediating markets. This activation of technology-mediating markets can lead to the activation of merger and acquisition channels as important technology or knowledge supply sources for the growth of medium enterprises in Korea. External channels for securing new technologies for medium enterprises are urgently necessary for both the project World Class 300 currently implemented by the Ministry of Knowledge Economy in 2013, which is intended to foster 300 global level medium enterprises and the project for fostering 3,000 medium enterprises which is a policy objective presented by the same department in 2012 and is now pursued. The external channels can be obtained only by activating technology-mediating enterprises.

### *3.2 Open Innovation Trends and Policy in Japan*

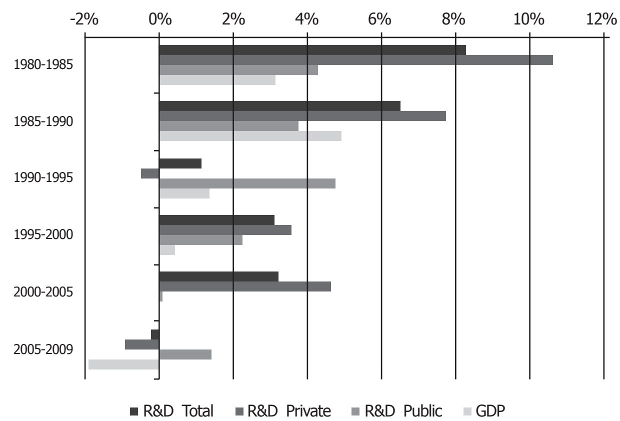
Man has described Japan's system of innovation as being in-house oriented and mainly driven by large corporations but external collaboration in R&D has been picking up in Japan since around the year 2000 (Motohashi, 2011). Conducting all required R&D internally is nearly impossible in mainly high-tech industries, such as electronics and pharmaceuticals, so shifting to an open innovation model is becoming a hot issue for Japanese companies. A report by the Research Institute of Economy, Trade and Industry shows that open-innovation activities, such as R&D collaboration with other firms and universities, have increased over time, and this trend is prominent particularly among small and young firms (Research Institute of Economy, Trade, and Industry, 2004).

As shown in Figure 1, in Japan, as enterprises' investments in research and development have decreased since the middle of the 2000s along with minus growth of GDP, overall research and development investments have decreased despite that the increase, small it may be, in government's research and development investments. In this situation, it is true that open innovation to secure new knowledge and technologies from the outside is becoming more and more important than ever.

Japanese enterprises' open innovation was reviewed as of the time when Japanese economy was recovered before the Lehman matter, as shown in Figure 2. Enterprises concentrated their energy on the development of their own core technologies and cooperated with universities for basic science or technology frontier projects and with SMEs for new areas of R&D.

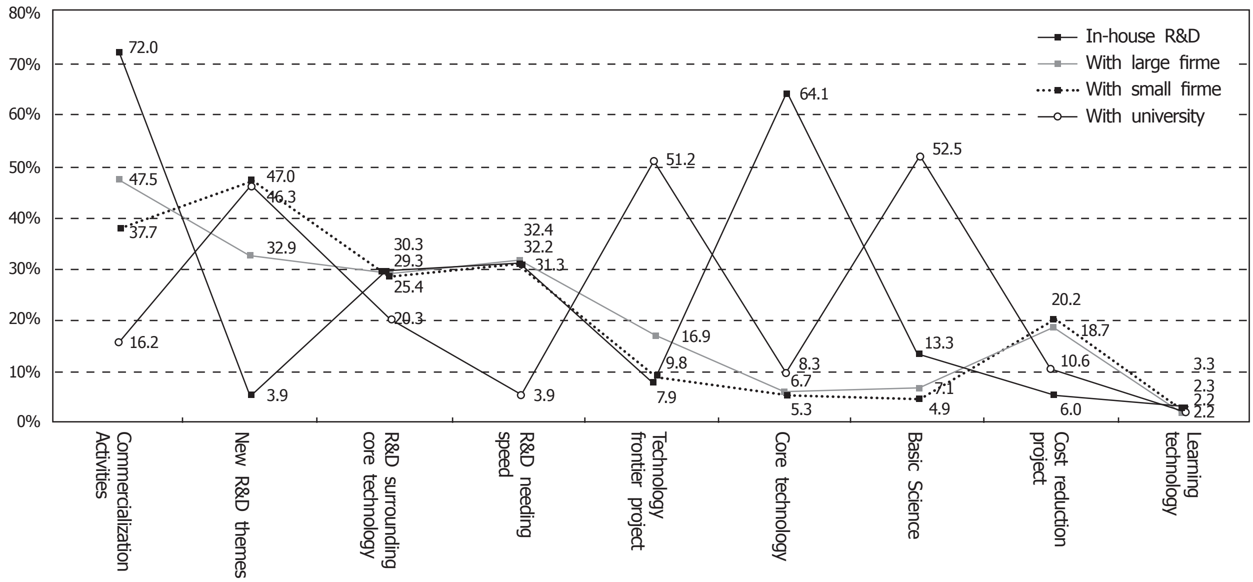
According to a comparative analysis of innovation activities by Japanese, U.S., and European firms in China, (1) foreign branches of Japanese firms are characteristically viewed as local branches of the home research facility, (2) foreign branches of U.S. and European firms conduct activities independently and actively collaborate with local universities and research facilities, and (3) the profit margins of Chinese branches of Japanese firms as a whole (Motohashi, 2010).

The Japanese government's open innovation policies can be estimated through budget structures among others. In 2010, of the total S&T budget amount of 3.57 trillion yen of Japan, 65% was executed by




Source: Motohashi (2011)

**Figure 1** Japan's annual growth rate of GDP and R&D




Source: Research Institute of Economy, Trade, and Industry (2004)

**Figure 2** Japan's in-house and collaboration R&D in 2004

the Ministry of Education, Culture, Sports, Science and Technology (MEXT), 15.1% was executed by the Ministry of Education, Culture, Sports, Science and Technology (METI), 4.3% was executed by the Ministry of Agriculture, Forestry and Fishery (MHLW), and 3.5% was executed by the Ministry of Agriculture, Forestry and Fishery (MAFF). Whereas the MEXT is mainly in charge of investments in universities' research and development, the METI is in charge of organizing R&D programs for industrial innovation.

An R&D project by the METI is typically organized by a group of companies working on large-scale R&D projects. These projects are funded by the METI and public research institutions, such as Agency for Industrial Science and Technology (AIST). The Very Large Semiconductor Integrated Circuit (VLSI) project and a substantial number of such projects in the area of advanced materials, mechanical engineering, energy development and environmental technologies have been introduced as the METI R&D projects. However, due to the increase in technological complexity and because huge enterprises in Japan have been equipped with their own technological capabilities, most of the METI's existing research projects have not produced successful outcomes. As an alternative for this situation, the METI presumed specific social and policy needs, such as "healthier and longer life" and is organizing research and development projects aiming at satisfying the needs.

One of the METI's new research and development projects is promoting innovation at SMEs. SMEs that had been the subjects of assistant policies of large enterprises' research and development projects previously have become the source of entrepreneurship, innovation, and job creation. Now, SME innovation policies, such as the Japanese Small Business Innovation Research (SBIR) have become a top priority. The uptrend can be sufficiently presumed from the fact that the SBIR budget has been showing an increasing trend with an increase by at least four times in 10 years from 10 billion yen in 1999 to over 40 billion yen in 2010. According to a questionnaire survey on the characteristics of open innovation of enterprises recently conducted on Japanese SMEs, Japanese enterprises with high technology levels and activated organizational culture to cooperate with internal or external organizations are actively implementing diverse kinds of open innovation based on ICT (Idota et al., 2012).

According to the interview with the councilor in charge of scientific technology at the Embassy of Japan in Korea, the Japanese government also recognizes that solutions for economic recession are effective preparation and implementation of open innovation policies and is preparing related policy alternatives. Among others, effectively developing national research and development projects reflecting social demand and effectively implementing the projects through industry-academy-research institute's manpower and space linking systems are important. In particular, he specified that activating small and medium enterprises' participation in national research and development to create new creative business and preparing global level technology systems and open innovation systems to continuously create new sustainable growth engines are tasks of Japan.

### *3.3 Open Innovation Trends and Policies in China*

China's innovation policies are largely divided into open-door policies or market-based open innovation systems before 2006 and indigenous innovation policies thereafter (Liu & Lundin, 2006; Wei, 1993; Bichler, 2012). Whereas China pursued the development of manufacturing industries and various other industries based on foreign countries' technologies and knowledge until 2006 after opening its doors to the world market, Chinese government's policies bases have been greatly changed once more since 2006 in order to raise its innovation ability.

Since the 1980s, China launched its economic reform and open-door policy toward a market-oriented economy of great openness (Liu & Lundin, 2006). The Chinese national innovation system at this time is basically a market-based open innovation system. As shown in Table 4, in 1990, research and development investments in China consist of investments by government led research institutes accounting for 50%, investments by universities accounting for 12%, and investments by enterprises accounting for 25% of all research and development investments in the country. However, the ratios were completely reversed in only in 10 plus some more years so that in 2005, investments by research institutes accounted for 21%, investments by universities accounted for 10%, and investments by enterprises accounted for 68% of all investments.

**Table 4** Changing of R&D expenditure ratio during key actors during open-door policy era (%)

| | 1990 | 1997 | 1999 | 2000 | 2002 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Research institutes | 50 | 43 | 39 | 29 | 27 | 23 | 21 |
| University | 12 | 12 | 9 | 9 | 10 | 10 | 10 |
| Enterprises | 27 | 43 | 50 | 60 | 61 | 67 | 68 |

Source: China Statistical Yearbook on Science and Technology 2004 (2006).

In fact, since its opening in 1978, China switched its economic structure into a market-centered one. However the practice for government research institutes (GRIs) led basic research projects to account for the majority of research projects was maintained until the early part of the 1990s. In this respect, the Chinese government carried out a drastic change. Toward the end of 1998, the State Council decided to transform 242 GRIs at the national level into technology-based enterprises or technology service agencies (Liu & Lundin, 2006). As a result, enterprises' research and development investments become to exceed 50% of all research and development investments when the 2000s began.

Meanwhile, in China, a great gap existed between GRIs and universities, which are knowledge-creating organizations, and enterprises, which are knowledge-utilizing organizations, that the situation underwent a major change during the period of open-door policies. Among others, GRIs universities were allowed and encouraged to build up their own spin-offs so that they could commercialize their technology directly. According to Statistics of University's industry, after 2137 universities' spin-offs were made in 1999, universities' spin-offs have been actively and continuously created including 2447 created in 2003 and 2355 created in 2004. Furthermore, as universities activated contract research for the industrial sector, most of universities' research and development activities were switched to studies for enterprises to the extended that after the ratio of funds from industrial enterprises to the entire universities' research and development funds was recorded as 33.3% and the ratio of funds from the government was recorded as 58.4% in 2000, the ratios were recorded as 38.9% and 53.8% in 2004.

Due to the open-door policies, in China, whereas market centered technologies rapidly developed in a short time, the composition or level of the technology in the period exposed the limitations as shown in Table 5. That is, the Chinese government placed emphasis not on patents based on creativity but on utility model patents or design patents centered on applications and improvement. In addition, whereas China recorded placed 26th in terms of the number of patent registrations in the U.S. in 2000 with 119 patents, Korea recorded placed 8th with 3,331 patents. Thereafter, whereas China took the placed 20th with 404 patients in 2004, Korea took placed 4th with 4590 patents. That is, in terms of quality and quantity of patents, China's records during the period open-door policies were not so great.

During the open-door policy era, both in the manufacturing sector and in high-tech industries, foreign direct investment (FDI) firms accounted for important parts of technology import, R&D expenditure, export, and employment. In the case of the manufacturing sector, whereas FDI firms accounted for 21% of research and development investments, 20% of technology import, 58% of technology export, and 14% of employment in 1998, they became to account for 29%, 48%, 76%, and 34%, respectively in 2004. In the case of high-tech industries, too, in the areas of pharmaceutical products, electronics and telecommunication, computer and office equipment, and medical equipment and instruments, FDI firms became to account for high ratios of tech import, export, employment, and R&D expenditures. In particular, FDI firms' shares of technology import and export became

**Table 5** The patents granted in China—By type of Patents in open-door policy era

(unit: piece)

| | 2000 | 2005 |
|---|---|---|
| Total patents granted | 105345 | 214003 |
| Invention patent | 12683 | 53305 |
| Utility model patent | 54743 | 79349 |
| Design patent | 37919 | 81349 |

Source: China Statistical Yearbook on Science and Technology 2004 (2006).

very high both in the manufacturing sector and in high-tech industries. During this period, although FDI firms' research and development investments and employment also increased, a stagnation phenomenon clearly appeared that the shares did not increased from the 20% zone and the 30% zone, respectively.

In this situation, China switched its policies into indigenous innovation policies in 2006. The "National Plan 2006–2020 for the Development of Science and Technology in the Medium- and Long-Term" is the current long-term S&T policy framework of China. The most interesting element of the new plan is the declared intention to strengthen "independent" or "indigenous" innovation (Liu & Lundin, 2006). The new innovation system maintains the central government, state-owned enterprises (SOEs), and universities and government-led research institutes as significant elements. They are now also developing innovation from private enterprises, multinational enterprises, and regional government with private enterprises significantly becoming the key players (Liu & Cheng, 2011). Its goal is to make China a globally significant innovative country through the implementation of this indigenous innovation strategy (Liu & Cheng, 2011). The current strategy of indigenous innovation has an intention to protect domestic enterprises from global competition while leveraging an exceptionally large domestic market to promote the diffusion of innovative products within China to some degree. By converting domestic enterprises from cost-limited to innovation-driven institutions, decreasing reliance on foreign technology, mastering cutting-edge industrial technology, and promoting economic and social development, the goal is to make China one of the world's recognized innovative countries (State Council of China, 2006). However, a problem is that the Chinese efforts in indigenous innovation are indispensably accompanied by the necessity to establish innovation networks that will have global impacts but the exceptionally large domestic market cannot accomplish this on its own.

Although China's per capita GDP was below $500 in 1978, it grew to a level close to approximately $3,500 by 2008. According to an evaluation from the outside, such as East-West Center, unfortunately, despite this outstanding economic growth, China's capability for technologic innovation had not developed as successfully. The objective of the Chinese government's indigenous innovation strategy established in 2006 was to invest 2% of Chinese GDP in research and development by 2010 and 2.5% of Chinese GDP in research and development by 2020.

The Chinese government's research and development investments accounted for 1.34% of GDP with a total amount of USD 30.56 billion in 2005 but the percentage increased to 1.70% of GDP with a total amount of USD 86.60 billion in 2009. In 2007, the total amount of research and development investments of China already reached seventh place in the world in absolute value. Specifically targeted national science and technology programs, such as 973 basic research, key technologies research and development program, 863 high-tech program, national key experimental laboratories program, and innovation fund for small and medium enterprises (SMEs) established by the Ministry of Science and Technology (MOST).

The best means of new Chinese policies is the changes to government technology-procurement policies which follow from the lessons of the best practices of South Korea and the United States. In fact, previous Chinese government's purchase policies were cost minimization and were not indigenous innovation promoting. The key concept of these policies is to make use of public funding to promote the development of innovative domestic products: they have a Chinese brand, use Chinese intellectual property, and have at least 51% Chinese ownership. In addition, these policies also require that in the case of key projects given by governments too, made-in-Chinese equipment should account for at least 60% of all core equipment.

In the new innovation policy era, the Chinese government adopted a strategy to implement 16 mega-projects by organizing research consortia in which private enterprises play more important roles. For example, in the "high-performance digital machine tools mega-project, coordinated by Ministry of Industry and Information (MII), the main participants include: Beijing First Machine-Tool Group, China Academy of Machinery Science and Technology, and Xian Jiaotong University. Another good example is the mega-project developing next-generation telecommunications technology in which Huawei and ZTE, as well as China Mobile, are all key players in the consortia.

However, ironically, despite the indigenous innovation policy of China, the ratio of investments in basic research that had decreased because the opening did not increase. Out of Chinese investments in research and development in 1995, the ratios of investments in basic research, applied research, and experimental development were 5.18, 26.39, and 68.43, respectively. However, these respective values were shown to be 4.70, 12.6, and 82.7, in 2008. That is, the ratios of investments in basic research have been rather decreasing.

In China, usually only large SOEs have historically been able to maintain a large number of scientists and engineers as employees, but this trend changed dramatically after the indigenous innovation policy started. For instance, the ratio of research and development manpower employments by SOEs that had accounted for most of private employments of scientists and engineers rapidly from 48% in 2002 to 25.9% in 2007. Enterprises' research fund ratios also showed the same phenomenon. By 2007 non-SOEs accounted for 49.4% of all noted enterprise segments' research and development funding while SOEs accounted for only 22.6%.

The 2006 adoption of a Chinese indigenous innovation strategy has resulted in significant changes in the realities of innovation practices within China through establishing government-led research consortia and key government procurement policy tools; China's government was able to increase its control over the resources available for innovation.

According to a questionnaire survey based study on the present state of Chinese enterprises' open innovation conducted in 2012, when the enterprises were requested to give answers about the importance of information sources in innovation activities through questions to which overlapping answers were allowed, of the enterprises' answers, 41.7% were firm itself or its affiliated group, 52.5% were user of consumers, 10.0% were government or public R&D institutes, and 8.3% were universities (Fu & Xiong, 2011). To questions regarding Chinese enterprises' sources of knowledge for open innovation, the answers indicated that the enterprises were actively implementing open innovation by obtaining knowledge from markets and research institutes beyond the inside of the enterprises, the most frequently from market information sources followed by internal sources and institution information sources in order of precedence.

### *3.4 Characteristics and Summary of Three Countries' Open Innovation Policy*

Open innovation policies are related to knowledge production, distribution, and consumption policies as shown in Table 1. Among them, knowledge production policies are not implemented alone. The relevant policies can be said to be open innovation policies only when they are implemented together with knowledge distribution or consuming policies (Chesbrough & Vanhaverbeke, 2011). Korean open innovation policies are understood as being gradually changed from knowledge production centered policies to diverse methods of knowledge distribution centered policies. Examples of these changes may include the preparation of diverse policies to activate the dispatch of university professors or researchers to enterprises of the reinforcement of policies for school enterprises and research institute enterprises.

On the other hand, Japan is evaluated to currently reinforce knowledge production-centered open innovation policies involving knowledge distribution and consumption. Examples of those policies may include the development of social problem solving type large national research and development projects and the establishment of research and development hubs in which universities, enterprises and national research and development institutions are to be situated together for joint research and development. The policies can be characterized by the fact that they concentrate more on knowledge production that can be accompanied by knowledge distribution and consumption.

Finally, in the case of China, the base of policies is considered gradually changing from focusing on knowledge consuming to emphasizing knowledge production and distribution simultaneously. The indigenous innovation policy is not a strategy to change the existing open innovation policy into a closed innovation policy but a strategy to reinforce knowledge production capabilities further and reinforce knowledge distribution and consumption based on the reinforced knowledge production capabilities.

## 4. A Few Misunderstandings on Open Innovation in Asian Countries

### *4.1 Open Innovation as a Channel of Not Monopolizing Innovation but Democratizing Innovation*

The innovation proposed by Schumpeter was innovation based on creative entrepreneurs' entrepreneurship at the beginning and the discussion was developed into innovation by groups of large enterprises later (Schumpeter, 1942). Thereafter, diverse innovation discussions were developed in Evolutionary economics and innovation studies and most of the discussions were centered on the theory of innovation systems. The theory of innovation systems is clearly more progressive that not only the Neoclassical theory, but also the Keynesian theory in that all of discussions of government's policies' intervention in System failure, National Innovation Systems, and Regional Innovation Systems have a theoretical basis of the government's more active intervention in markets. However, most Asian countries including not only Korea, but also Japan and China have characteristics distinguished from innovation studies in Europe or in the USA that are linked to political progressiveness in that they approach innovation policies from practical viewpoints. Therefore, the fact that the open innovation has an aspect of democratizing innovation as strong as user innovation should not be overlooked in that the open innovation becomes the basis of the innovation logics of SMEs or individual business founders based on creative ideas. That is, rather than having a value as an innovation strategy of large enterprises having sufficient research and development capabilities or a policy for the strategy, open innovation can be a strategy more suitable for SMEs that promote creative innovation and sustainable growth based on diverse external ideas. In addition, its value as a means of the start-up of individuals' open innovation business models based on ideas and knowledge existing in the world as a means of sustainable economic and social growth should not be overlooked (Yun, 2010).

*4.2 Open Innovation is Not "Not Unique" but "Very Unique"*

Diverse discussions of which the logics are already connected to the theory of open innovation or the cores of the logics are similar to that of the theory of open innovation already exist in existing economic or business administration theories such as the discussion on external effects that took notice of the effect of external economy that surpasses existing economic effects in economic theories or customer relationship management that took notice of customers' demands, expectations, or opinions in business administration. However, the importance and value of the discussion on open innovation that explicitly took notice of enterprises' or diverse economic units' pursuit of new innovation based on external knowledge and technology that they did not create or their transfer to the outside or utilization of internal knowledge and technology that are not utilized cannot be overlooked. In particular, the fact that in Asia, where the Confucian tradition is strong, in the state where the importance of technology-based economy has been just established in economic systems, cultures that makes enterprises and economic units be unwilling to acknowledge or take notice of the value of open utilization of technologies and knowledge not created by them are overflowing cannot be denied. Whether another hidden reason Japanese economy that had been even expected to go beyond the economy of the USA fell into recession at the time when knowledge distribution and consumption became more important than internal production of knowledge is the culture in Japan, which is hostile to open innovation should be watched. Open innovation is a phenomenon having quite unique characteristics which enable enterprises or governments to obtain high economic profits only when they have invested considerable amounts of finances and strategic costs.

*4.3 Open Innovation Needs, Not No-R&D Investment but Enough R&D Investment.*

The paradigm of open innovation has come to appear following the advent of knowledge-based economy in which the amounts of knowledge and technology existing outside innovating bodies, such as enterprises, have become sufficiently large. In addition, in particular, open innovation has come to be watched as an innovation strategy when enterprises that have accumulated sufficient technology and knowledge on their own became to take notice of innovative external technologies or ideas not owned by them. In other words, only those enterprises and countries that have sufficient innovation capabilities on their own can be equipped with the insight and ability to realize the necessity of external knowledge and technologies and acquire the knowledge and technologies. This is the reason for the fact that the current core technology management strategies of global leading enterprises in the USA and in Europe are open innovation strategies. The reason Samsung recently established a large research institute in Silicon Valley and had the research institute take full charge of open innovation strategies is also based on this context. The reason technology-based global cutting-edge enterprises and countries where world class cutting-edge industries have developed are leading in open innovation strategies and policies is that only these enterprises and countries are equipped sufficient internal innovation capabilities based on sufficient research and development investments and became to pursue open innovation capabilities.

In other words, open innovation strategies and policies are not something for which internal research and development investments are unnecessary but are strategies and policies that must be pursued on the basis of sufficient internal research and development investments. Asian enterprises or countries that are just being equipped with their own research and development capabilities should never overlook the necessity of internal research and development investments as they face the open innovation strategies and policies pursued by Western advanced countries and cutting edge enterprises.

## 5. Policy Proposals for Activating Open Innovation in Asian Countries

Although China is in a little different situation, the reasons why open innovation has not been activated commonly in Korea and Japan appeared both in interviews with persons in charge of policies of the two countries and literature analysis. Among others, important reasons are that excellent researchers are concentrated on universities and that even if the researchers create excellent study outcomes with enormous economic performance, they would never move to enterprises or markets. That is, the lack of researchers' fluidity is the most serious hindrance factor for open innovation. Therefore, the first proposal for Asian countries' open innovation policies is that the countries should be equipped with diverse, stereoscopic, and practical policy systems that can enhance researchers' fluidity. Policies for enhancing researchers' fluidity, which coincide with the entire life cycles of technologies, should be prepared to enable university professors or researchers of national research institutes who created excellent study outcomes to willingly move to enterprises with the relevant technologies, stay there for the life cycle of products from the relevant technologies and come back to universities or enterprises to dedicate themselves to studies when necessary. These policies are more necessary because researchers in Asian countries where the Confucian tradition is strong have cultural traditions that make them avoid transfers from universities or research institutes to enterprises.

It is well known that the arrow information paradox exists in relation to knowledge and technology transactions (Chesbrough, 2003). The paradox is that demanders are not willing to pay prices unless the knowledge and technology which are the subjects of transactions are well known and when they have come to sufficiently know knowledge and technology, which are the subjects of transactions, they try to use the relevant knowledge free of charge without pay prices. An important base for overcoming this arrow information paradox is trust (Fukuyama, 1996). Unlike in Western society where the tradition of capitalism is strong, it is well known that in Asian countries, cultures for trust have not been sufficiently accumulated yet not only in transactions of tangible goods, but also in transactions of intangible knowledge and technology. In Western countries centering upon USA, diverse knowledge and technology-mediating enterprises appeared to overcome the arrow information paradox and activate technology transactions in diverse methods. Therefore, among others, Asian countries should prepare diverse stereoscopic cultural and institutional policies that can overcome the arrow information paradox in knowledge and technology transactions and activate knowledge and technology transactions. The activation of knowledge and technology transactions in markets is the most concrete open innovation activation policy. To this end, in the case of Asian countries in particular, technology and knowledge transaction activation policies should be established in comprehensive dimensions, including culture, systems, and policies.

The present paper summarized open innovation policies of Asian countries including Korea, Japan, and China at a limited level. Therefore, comparing open innovation policies of Asian countries, establishing analysis frames to compare and analyze open innovation policies of Asian countries and those of Europe or the USA, and precisely comparing and analyzing the open innovation policies from the viewpoint of the production, distribution, and consumption of knowledge and technology are left as tasks for follow-up studies.

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