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'LEAPFROGGING' IN THE INFORMATION ECONOMY: LESSONS FOR DEVELOPING COUNTRIES

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ABSTRACT

This paper discusses a new empirical framework to measure 'leapfrogging' in the information economy. Here, performances of twenty-five countries were compared based on two broad categories called as '*Reach' factors* (ICT infrastructures that facilitate connectivity in the information economy) and '*Rich' factors* (intellectual/human capital, innovation and interaction/strategic cooperation). Using a statistical pattern recognition method, the countries are classified into five bands (Band 1: Pace-Setters, Band 2: Adepters, Band 3: Adapters, Band 4: Adopters, and Band 5: Starters). These bands are tracked over the sample period 1995 to 2001. The empirical result showed two types of leapfrogging that have occurred in the sample period, that is, *inter-band leapfrogging* and *intra-band leapfrogging*. This study also showed that countries that have higher investment in the Reach and Rich factors also have higher labour productivity, industrial productivity, service productivity and consequently overall productivity. Most of the developing countries were classified in Band 5 (low Reach factors and low Rich factors). Results from this study also identified key policies and strategies to close the 'Reach-Rich' gap between developing and more evolved countries.

Keywords: convergence, leapfrogging, information economy and developing countries.

"It is not the strongest of the species that survive, nor the most intelligent, but the ones most responsive to change"

-Charles Darwin

1. INTRODUCTION

Developments in technology, more specifically information and communication and technology (ICT) over the last two decades have transformed the global landscape. Some would argue that developments in ICT have not only transformed the traditional factors of production, but also social and political dimensions globally.

Scarcity of land in the information economy (sometimes referred to as the knowledge economy or new economy) is becoming less relevant, as firms move from "places to spaces". In terms of shortage of skilled workforce, the digital economy allows firms to outsource work to workers in distant countries with no compromise in quality or time. 'Virtual teams' and 'Virtual organizations' are becoming a common place in the information economy, and they transcendent national boundaries. Access to capital from the global market place is also made easier by the digital framework.

Various empirical studies have shown that ICT enhances productivity, efficiency and innovative capabilities of organizations around the globe. For example, Brynjolfsson and Hitt (1995) showed that ICT has increased the productivity of the firms and it has created substantial value for customers. Broersma and McGuckin (2000) showed that ICT had positive and significant impact on productivity in the retail and wholesale industry in the Netherlands. Lal (2000) showed that ICT not only complement efforts to improve quality of goods and services, but also enhances the speed and flexibility of production in India. Stiroh (2001) and Colecchia & Schreyer (2002) have showed that the ICT sector played a key role in the sustained productivity and economic growth in the US after the middle of 1990s.

Many attribute ICT to be an important catalyst for speeding up the forces of globalization and liberalization. The speed at which ICT is changing the global social order is clearly highlighted in the following quote by a leader from a developing country.

> *"Although the use of IT in the economic development and well-being of the people is not too clear, there is no doubt that the Information Age will have an impact on Malaysians. We cannot eat, wear, or ride on information, but information will determine the performance of industries of the future. Protecting industries and the economic environment will no longer be easy. Even if WTO fails to breakdown national barriers, IT will"*

Tun Dr. Mahathir Mohamad (1996)
Former Prime Minister of Malaysia

Not to be left behind in the information age, many developed and developing countries are spending billions of dollars upgrading their ICT infrastructure, infostructure, human capital and institutions to adapt to the new world order. To date, the developed economies and some countries in the Asian region (e.g. Singapore, Japan, Taiwan, and South Korea) have enjoyed the direct and spillover benefits of ICT. Empirical evidence also suggest that high ICT adoption rate in some newly industrialized countries, (e.g. Singapore, South Korea, and Taiwan) have enabled them to 'catch up' with the more advanced countries in terms of competitiveness and wealth accumulation (Kraemer and Dedrick, 1999).

A new world order is being shaped by the more ICT savvy countries, while many developing countries are grappling to keep pace with the ICT developments, far less to 'catch up' with the leaders. The digital divide between the developed and developing countries are increasing due to the different adoption rate to the information society. Wijkman and Afifi (2002) highlighted that only 7 percent of the world's population is connected to the Internet. This shows that billions of people, mostly from under-developed and developing countries are still untouched by the ICT revolution.

The digital divide between the 'have' and 'have nots' are attributable to many causes. The main causes of the digital divide are the lack of proper ICT infrastructure and the development of human capital to adapt to this new medium of communication. For example, in Africa, only a small percentage of Africans (one in every thousand) enjoy Internet connectivity due to lack of ICT infrastructures (Amoako, 1998).

A more serious concern that plagues many of the developing world is the lack of vision and focused policies to empower the people to be part of the information revolution. The macro and micro policies in many of these countries do not keep up with the technological changes that are taking place globally. The primary focus of this paper is to examine the patterns of ICT adoption in twenty-five countries over the past seven years. We examined these countries based on several 'Reach' and 'Rich' characteristics. The former captures the level of connectivity in countries and the latter measures the degree of productivity, innovation, and competitiveness in the economy. This study is an extension of the study conducted by Nair and Kuppusamy (2004), which examined the trends of convergence and divergence among several developed and developing countries over the period 1995 to 2001.

In this paper, we provide a new empirical framework to capture leapfrogging with respect to a wide range of characteristics. Our approach does not only capture technological leapfrogging, but also leapfrogging with respect to ICT infrastructure, intellectual capital/human capital, innovation and interaction (strategic partnership). We also introduce two types of leapfrogging. The first is called *Inter-Band Leapfrogging*. This is the movement of countries between bands, bypassing one or more bands. The second type of leapfrogging is called the *Intra-Band Leapfrogging*, where we capture the movements of countries within a band, but bypassing one or more countries.

Using a new empirical method we will assess if there were inter-band and intra-band leapfrogging among the twenty-five countries (mixture of developed and developing countries) over the 1995 to 2001 period. Based on our empirical findings, we will identify the factors that have helped some of these countries to leapfrog.

The result will identify common prerequisites and conditions that will be necessary in order for leapfrogging to take place. This information would be valuable for developing countries in formulating policies to enhance their competitive position in the information economy, and to help them to 'catch up' with the more evolved economies.

The rest of this paper is organized as follows. In Section 2, we provide a review of the literatures on 'conditional convergence' and 'leapfrogging'. In Section 3, we introduce a new framework to capture leapfrogging in the information economy. The empirical method to measure leapfrogging and the data used in this study are discussed in Section 4. In Section 5, the empirical analysis for the twenty countries will be reported. In Section 6, a discussion on the policies/strategies that were implemented by countries that have leapfrogged and achieved sustained growth will be examined. In Section 7, the concluding remarks and future research directions will be given.

2. LITERATURE REVIEW ON 'CONDITIONAL CONVERGENCE AND 'LEAPFROGGING'

There are different schools of thought on convergence of economies, or why some less-developed nations are able to 'catch up' with the more advanced nations. One of the earliest works in this area is by Solow (1956 and 1957), who suggested that less developed countries tend to converge faster towards a steady state than countries that are more developed (also known as β- convergence). Solow argued that as income in the less developed countries increase as it approaches the steady state, the total factor productivity and growth declines. In the long run, the differences in the growth rates of the countries are smaller (also known as σ-convergence).

There are a number of studies, which supports the neoclassical growth theory, among which is the work done by Cass (1965), Koopmans (1965) and Mankiw et al., (1992). The key assumptions of these studies are that that technologies, population and the market structures in these economies are homogeneous.

However, other economists have argued that the above assumptions may not hold. They argue that poor countries do not have equal access to technology as the developed countries. Further, the cost of technology and knowledge differs across underdeveloped, developing and developed countries, resulting in significantly different levels of productivity growth (i.e. labour productivity, industrial productivity, service productivity and overall productivity) across these countries.

The *new growth theory* suggests that technological gap and absorptive capabilities are important ingredients for poor countries to catch up with the more developed economies. Absorptive capability refers to the ability of human capital to absorb new technologies, and use their skills to achieve higher efficiency and productivity. Nelson and Phelps (1966) argued that the growth of total factor productivity is a function of both the human capital level and technological gap. Thus, an educated labour force is expected to have the ability to adopt new technologies (technology transfer) much better and faster than less educated labour force, resulting in higher growth levels.

The *endogenous growth model* [Romer (1990), Gross and Helpman (1994)] showed that the stock of human capital has a significant effect on the growth rates of an economy. They argued that the stock of human capital is an important determinant for nations to be innovative and productive.

Lucas (1990) argued that physical capital does not migrate from wealthier to poorer countries because of cheap labour in poorer countries. He argued that human capital is an important complement for investment in physical capital. Thus, highly skilled workforce tends to attract high-end foreign direct investment (FDI).

School enrolment rates and average years of education (Barro and Sala-i-Martin, 1991) were found to be an important contributor towards economic growth, and in enhancing the convergence between rich and poor countries. The authors concluded that a poor country has a potential of growing faster than richer countries if there is significant upgrading of human capital.

There are other studies in the literature that attribute cross country differences in economic growth to differences in the initial human capital stock, rate of investment in physical capital, capital deepening due to technology, rate of investment in education, government policies, and political stability. They include studies by Pigliaru (1999), Benhabib and Spiegel (1994), and Mankiw et al. (1992), Barro and Sala-i-Martin (1995).

There has been growing body of literature focusing on the theoretical concept of leapfrogging and its economic implications to developing countries (for e.g. Abramovitz, 1986; Lee and Lim, 2001 & Wijkman and Afifi, 2001). Leapfrogging is defined as the process of "bypassing some of the process of accumulation of human capabilities and fixed investment in order to narrow the gaps in productivity and output that separate industrialized and developing countries" (Steinmueller, 2001).

The common themes in many of these studies are better connectivity and informatization of the country leads to increased wealth and productivity. In this context, ICT is seen as an important enabler for developing countries to 'catch up' with the more developed economies.

Santer (1995) argued that knowledge is seen an important facilitator for developing countries to jump stages of technological progress with the high possibility of stimulating economic and social growth in the country. More recently, Stiglitz (2003) argued that for developing countries to 'catch-up' with the more evolved countries, greater priority should be given to investment in human capital development, innovation and ICT infrastructure. He also argued that strategic cooperation between the government, industry and institutions of higher learning would be an important catalyst for spurring innovation that is relevant for the information economy.

A number of studies have identified the Internet as an important engine for the developing countries to leapfrog into the information economy. Internet makes cost of communication cheaper, accessing information faster, and connecting to the global village easier. Gourova et al., (2001) highlighted that while most developing countries are still being hampered by under-investment in ICT infrastructure and poor regulation, the Internet has played a key role in connecting these countries with the developed economies. The increased connectivity around the globe is also due to the rapid developments in electronic commerce.

Other studies have highlighted the importance of education as a major factor for ICT diffusion in a country. They argued that successful ICT diffusion requires not only installation of the ICT infrastructures, software, and application of systematized knowledge, but also a good understanding, management and contextual application of the technology [see for example, Davison et al., (2000); Lee (2001) and Caselli & Coleman (2001)]. This requires the creation of adequate ICT education and training environment.

As highlighted earlier, ICT infrastructure alone will not suffice leapfrogging. Other complementing factors, such as appropriate legal framework, skillful and knowledgeable human capital, local and international cooperation, down stream integration requirements and political environment are also important prerequisites for a country to achieve sustainable growth.

In this section we have discussed various theoretical frameworks and models that have been used in the literatures to capture the conditional convergence and the leapfrogging phenomenon. However, most of the studies have examined only a subset of the variables that are important for leapfrogging. In the next section, we will outline a general framework to capture leapfrogging in the information economy.

3. LEAPFROGGING: A NEW THEORETICAL FRAMEWORK

Many of the models and frameworks in the literatures capture leapfrogging from a very narrow standpoint, that is, 'technological leapfrogging' or 'technological catch-up'. However, these models have been framed within the context of the neoclassical theory. In this paper, a general framework that captures the leapfrogging phenomenon in the information economy is provided.

Here, leapfrogging does not only require technological advancement, but also appropriate ICT infrastructures, innovation, intellectual capital, institutions and interactions (strategic partnerships) which caters for the developments in the information economy.

The primary objective of this paper is to examine the pre-conditions that will facilitate developing countries to 'catch-up' with the developed economies. In this paper, we define leapfrogging as the process in which a country is able to bypass the various stages of developments in terms of the *Reach* factors (ICT infrastructures that facilitates connectivity) and *Rich* factors (intellectual/human capital, innovation, interaction or (strategic/smart partnership), and institutions) to close the gap with the more informatised countries in terms of productivity and competitiveness.[1]

In this paper, we have extended the 'Reach-Rich' analysis given in Evans and Wurster (1997) to measure macro level competitiveness of countries. A broader definition for the 'Reach' and 'Rich' indicators are given below.

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[1] In order to measure leapfrogging, we have used the 'Reach-Rich' analysis outlined in Evans and Wurster (1997, 2000). Evans and Wurster define 'Reach' as the number of people who participate in the sharing of information. Meanwhile, Rich is defined as the quality of information in terms of accuracy, bandwidth, customization, interactivity, relevance, and security. They argued that firms would be able to overcome the tradeoff between Reach and Rich if there is explosion of connectivity and dissemination of standards across the economy. However, this framework caters only for micro level (firm level) developments.

The Reach indicators for the information economy are characterized as follows:

- *ICT infrastructure* - access to ICT facilities such as personal computers, software and Internet.

The 'Rich' indicators are categorized into six dimensions. They are as follows:

- *Intellectual/Human Capital* – level of literacy, ICT literacy, competencies, and knowledge for personal and social development. This includes human capital development for the information economy.
- *Innovation* - this covers the amount of R&D investments (public and private sectors), the number of R&D personnel, commercialization of research findings, ability to attract external funds for research, number of patents developed and patents that have been commercialized.
- *Institutions* - the development of a new institutions and upgrading of old institutions to facilitate smooth transition and efficient operation in the information economy. This includes development of an information tracking systems, patent registry, Intellectual Capital Bank and Institutions of Corporate Governance.
- *Interaction (Strategic/Smart Partnerships)* – the level of sharing of technology and knowledge among the economic agents in the country and across the world.
- *High Value* - encompasses: efficiency and productivity (quality); economies of scale (cost per unit falls); economies of scope (one technology to do multiple-tasking); technology transfer; adaptability and flexibility (e.g. customization of products and services), mobility and quick response time.

3.1 Stages of Development in the Information Economy

There are considerable amount of literatures on the different stages of economic development countries undergo, from agrarian to production based economies and finally to information/knowledge based economies. The levels of adoption to the latter stage of development depend on the level of deepening of the ICT infrastructure, intellectual/human capital, innovation, interaction (strategic partnerships) and institutions. In this paper, the different stages of adoption to the information economy are characterized as the Imitation, Integration and Innovation stages of development. Descriptions of these stages of development are given below.[2]

Imitation Stage

In this stage of development, both the Reach and Rich indicators are low. Most of the sectors in the economy are driven by basic factors of production. The inflow of foreign direct investment (FDI) into the country is to take advantage of the abundant cheap factors of production. The inflow of

[2] The different stages of development do not exactly explain everything about a country's stage of development -- thus, no country will fit exactly to the descriptions. The characterization provided is a very general description of the stages of development in the information economy. The same is true for the band classifications of the countries.

FDI's are sensitive to macroeconomic factors such as labour cost, exchange rate movements and other factors that have a direct impact on the cost of production in the country.

There is abundance of unskilled and semi-skilled workers. Given the low level of skilled workforce, much of the technology and 'know-how' is from the developed countries. The level of innovation by domestic firms is also very low.

In the absence of proper ICT infrastructure and low skilled human capital, foreign firms develop their own infrastructure and training systems to support their operations in the country. Thus, access to foreign markets is via the foreign firms. Supporting industries in the countries in this stage of development are fairly underdeveloped.

Integration Stage

In this stage both the Reach and Rich factors are at moderate levels. The absorbability of the workforce is higher than countries in the Imitation stage. This allows for better assimilation of foreign technology and 'know-how'. The foreign technology and 'know-how' are integrated into the main core economic activities to enhance the level of efficiency and productivity.

There are also improvements in the foreign technology transfer that takes place in this phase of development. However, much of the innovations are at the fringe to tailor-make the products and services for domestic or regional markets. There is significant strategic partnership between firms from countries in this stage of development and firms from more advanced countries in the areas of R&D and technology cooperation. Supporting industries are developing.

Innovation Stage

In this stage of development both the Reach and Rich indicators are high. The standard of living is high in countries in the innovation stage. Thus, advanced buyers market is large. Further, given the high level of the Rich and Reach factors in this stage of development, the numbers of advanced suppliers are also high. With high number of advanced buyers and suppliers, there is significant competition to constantly improve the goods and services.

Further, with the high cost of living, there is significant pressure for firms to constantly innovate and achieve cost advantage via more advanced technology. New technology becomes a vital factor for firms to extend their market reach – thus, achieving *economies of scale*. Intensive innovation allows firms to pursue *economies of scope*. Countries in this phase also have world class supporting industries that develops into important economic clusters. There are significant horizontal and vertical deepening of these clusters. FDI's into countries in this phase of development are less sensitive to the macroeconomic fluctuations.

In this paper, we argue that within the different stages of development, there are five different homogenous bands/clusters of countries with different level of competitiveness in the information economy (as shown in Figure 1).

In the Innovation Stage, there are two bands of countries, which we refer to as *Band 1- Pace Setters* and *Band 2-Adepters*. In the Integration Stage, there are also two distinct bands of countries, which we refer to as *Band 3-Adapters* and *Band 4-Adopters*. Finally, in the Imitation stage, we have one band of countries, which we refer to as *Band 5 – Starters*. Detailed descriptions of the bands are given below.

Band 1: Pace Setters

Countries in this band have highly advanced ICT infrastructures, both locally and globally. Human capital development is the highest priority in national development policies. Investment in education per capita is very high. Further, human capital development is linked with the socio-economic requirements. These countries also have very high level of skilled workforce in most of the sectors of the economy.

Total investment in R&D is very high in these countries, and these countries tend to set the pace for innovation. There is significant amount of interaction between the government and the private sector in enhancing the innovative capability. These interactions are strong, both domestically and globally. Countries in these bands have highly developed institutions to facilitate the information economy. In many cases, these institutions become global benchmarks for countries in other bands.

Band 2: Adepters

Infrastructures in countries in this band are highly advanced – linked to the global network. Quality of human capital development and per capita human capital investment are high. R&D investment is high and there are significant developments of new technology in key economic sectors. Countries in this band are highly adept in sourcing specific technologies from other countries that have more superior technologies. There are strong partnerships between the government and the private sector in enhancing the human capital, and innovative capabilities of the countries. Institutions for the information economy are fairly developed.

Band 3: Adapters

Infrastructures in key sectors of the economy are highly developed. Level of investment in human capital development is high, but lower than countries in Band 1 and Band 2. There are significant innovation in these countries, however, much of the innovation depend on technologies of countries in higher bands. In some sectors, innovation tends to be improvements of existing technologies from countries in higher bands. Given that much of the innovation in these countries depends on technologies from countries in the higher bands, there is significant cooperation between firms in Band 3 and the higher bands. Some institutions for the information economy are developed – often imitating that from countries in Band 1 and Band 2.

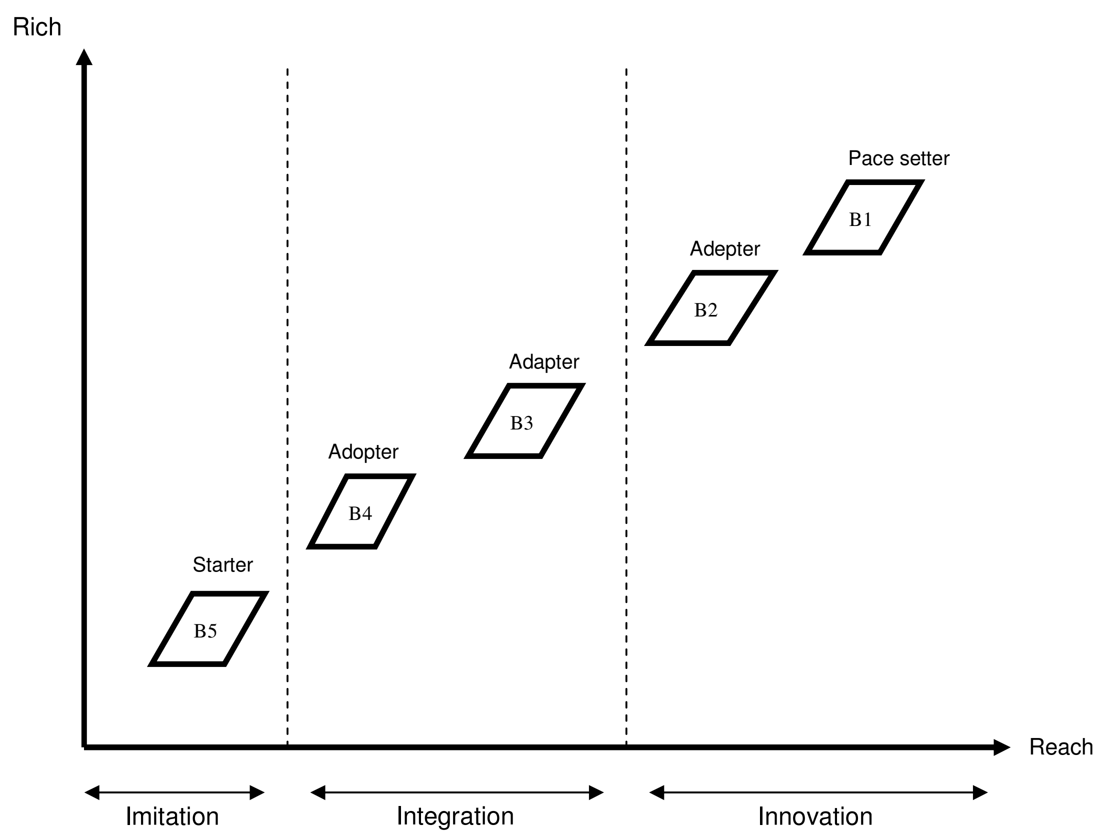
Band 4: Adopters

Infrastructures in these countries are developing. Investment in human capital development and innovation are modest. Much of the innovation involves using technologies from other advanced countries to improve productivity and efficiency in the domestic economy. Interaction between firms, both domestically and internationally are modest but developing. Institutions for the information economy are also developing.

Band 5: Starters

In these countries, ICT infrastructure developments are at an infant stage. There is also very low investment in human capital development, thus proportion of skilled workforce very low. Further, the level of R&D investment is also very low – low innovative capability due to limited absorptive capabilities of the workforce. Linkages between the government and the private sector are weak and fragmented. Institutions for the information economy are non-existent.

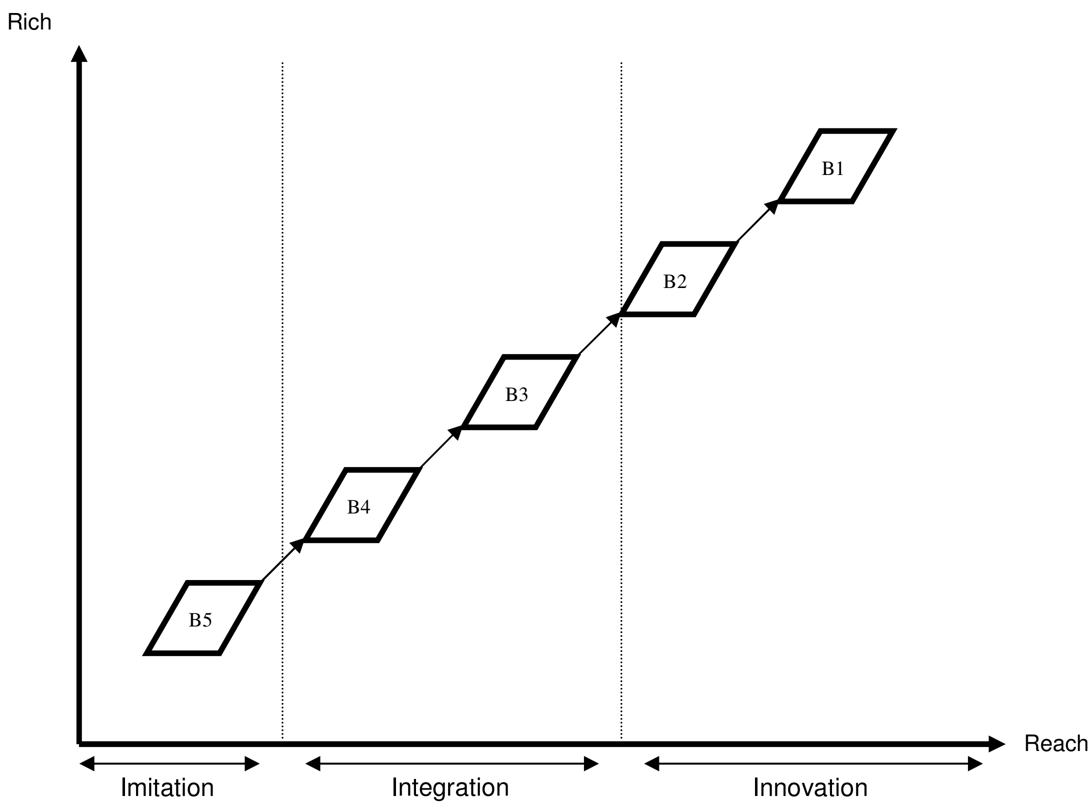
Figure 1: Stages of development in the information economy



3.2 A Conceptual Framework of the Leapfrogging Phenomena

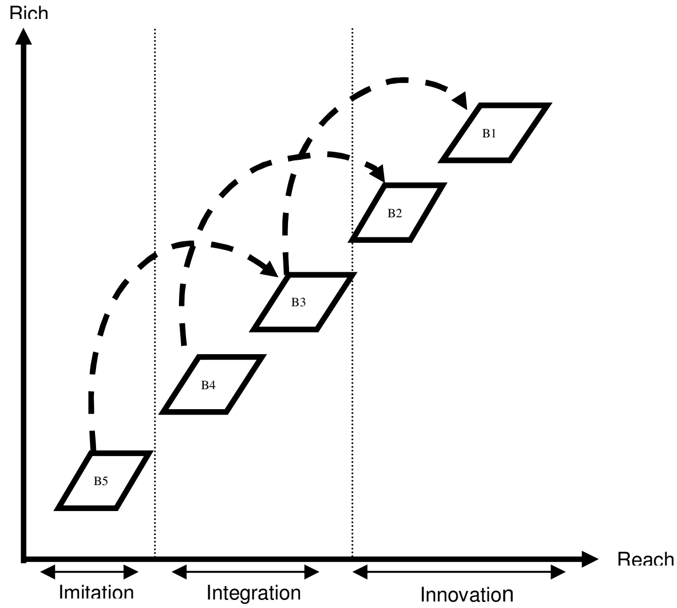
In this paper, we assume that at a given moment in time, each country is in a specific band. Countries in the same band are homogeneous in terms of development, while developments of countries in different bands are heterogeneous. The stage of developments of countries and bands are also time-variant. In traditional economic theory, countries undergo linear stages of economic development, that is, countries move from Band 5 to Band 4, and finally to Band 1, as shown in Figure 2.

Figure 2: Linear Stages of Economic Development



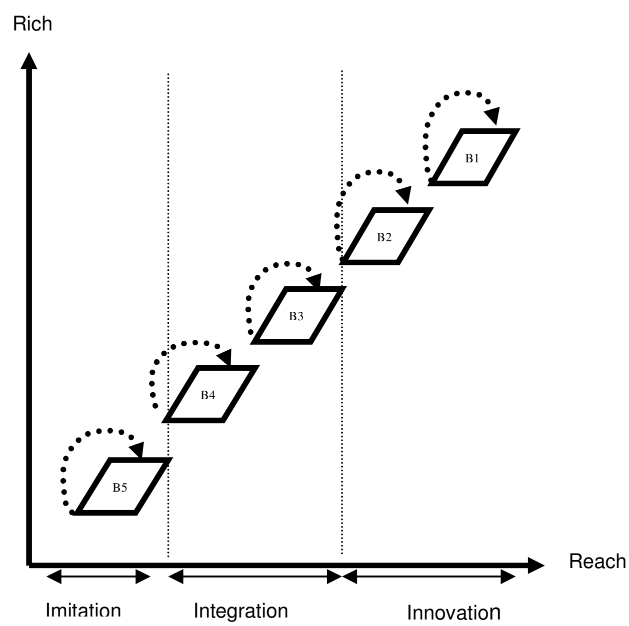
In the information economy however, the stages of development can be non-linear, in that countries can leapfrog, i.e. bypass one or more stages of development. In this study, we characterize two types of leapfrogging. The first is called the *Inter-Band Leapfrogging*. This is the case when a country moves in the direction of increasing Reach and/or Rich variables by passing one or more stages of developments (i.e. Bands). Here, we could have a country moving from Band 5 to Band 3 (bypassing Band 4), Band 4 to Band 2 (bypassing Band 3) or Band 3 to Band 1 (bypassing Band 2), as illustrated in Figure 3. Note that countries in Figure 3 bypass one stage of development. There is also the possibility of countries bypassing more than one stage of development (Band).

Figure 3: Inter-Band Leapfrogging (Non-Linear Economic Development)



The second type of leapfrogging is called the *Intra-Band Leapfrogging,* which is defined as a process in which a country bypasses one or more countries in the same band, as shown in Figure 4.

Figure 4: Intra-Band Leapfrogging (Non-Linear Economic Development)



4. AN EMPIRICAL MODEL TO MEASURE LEAPFROGGING

The empirical method used in this paper is a statistical tool to identify distinct homogeneous Bands (substructures) in a data set. Assume that the sample consists of *n* countries with *k* characteristics (Reach or Rich factors). The goal is to find a way to group these countries into one of the *G* homogeneous bands (stages of developments), denoted as $\{B_{1t},...,B_{Gt}\}$ at some period *t*. More formally, let the sample set be denoted as $\mathbb{S}_t$, and the *j*th band as B_{jt} at time t. Note that $\mathbb{S}_t = \bigcup_{j=1}^{G} B_{jt}$. Let C_{ijkt} be the *i*th country, belonging in *j*th Band, with *k* characteristics at time *t*, where i = 1,...,*n*; j = 1,...,*G*; *k* = 1,...,*p*; and, *t* = 1,...,*T*.

At given moment in time *t*, each country must be at a specific stage of development (i.e., band). Thus, $C_{ijkt} \in B_{jkt}$ for *j* = 1,...,*G*. Further, given that the stage of developments are assumed to be distinct, a country cannot be in two stages of developments, that is, $B_{j_1kt} \cap B_{j_2kt} = \varnothing$, for $j_1 \neq j_2$. Allocating *n* countries into *G* bands is a *NP hard problem*. Everitt (1993) showed that sorting *n* observations into *G* subgroups is a *Stirling Number*, that is, $S(n,G) = \frac{1}{G!}\sum_{j=1}^{G}(-1)^{G-j} C_j^G j^n$. For example, allocating 15 countries into three bands will require us to examine $S(n,G) = 2{,}375{,}101$ possible band configurations. Examining all possible band configurations seems unreasonable in a practical setting. In this section, we outline efficient method to determine band membership for the twenty-five countries.

4.1 The Algorithm

To optimally allocate the countries into the respective bands, we employed the widely used *K-Means* clustering method (Hartigan and Wong, 1979). The leapfrogging algorithm is given as follows:

STEP 1: At period *t*, partition the countries into *G* bands (initial band configuration).

STEP 2: Reallocate each country into the different *G* bands such as to minimize the 'within-band sum of squares':

$$f_t = \sum_{j=1}^{G}\sum_{i \in B_{kj}}\sum_{k=1}^{p}\left(C_{ijkt} - \overline{B}_{jkt}\right)^2$$

where, $\overline{B}_{jkt}$ is the k-dimensional centroid for Band *j* at period *t*.

STEP 3: Repeat the assignment of countries into the *G* bands *q* times (repeat STEP 2 *q* times). The computed objective functions for the *q* assignments are: $\left\{f_t^{(1)},...,f_t^{(q)}\right\}$, where $f_t^{(1)} > ... > f_t^{(q)}$.

STEP 4: Stop iteration until satisfy the convergence criterion, $\left| f_t^{(q)} - f_t^{(q+1)} \right| \le \varepsilon$, for some value of ε.

To rank the bands according to the classifications given in Section 3 and rank countries in each band, we incorporated two ordering criterions to the above algorithm.

4.2 Inter-Band Ranking Criterion

Let k_{j1}^* be the number of characteristics in Band *j*1 that is greater than another band called Band *j*2 (k_{j1}^* is called the lead factor for Band *j*1). Similarly, let k_{j2}^* be the number of characteristics in Band *j*2 that is greater than Band *j*1 (k_{j2}^* is called the lead factor for Band *j*2). If $k_{j1}^* > k_{j2}^*$, then *j*1 < *j*2, which implies that B_{j1} is in a higher stage of development than B_{j2}. In the case when $k_{j1}^* < k_{j2}^*$, then *j*1 > *j*2. Hence, B_{j2} is in a higher stage of development than B_{j1}. Note that the above ranking satisfies the *transitivity property*.

If $k_{j1}^* = k_{j2}^*$, then we examined the percentage difference between the characteristics for the two bands. If the values of the characteristics for Band *j*1 are higher (in percentage) than Band *j*2, then Band *j*1 is treated as the band with a higher stage of development, and vice-versa. Note that if the percentage differentials in the characteristics for the two bands are very close, then the stages of development for these two bands are considered very close too.

4.3 Intra-Band Ranking Criterion

To rank countries within a specific band, we also impose a similar ranking rule as given above. Let k_{C1}^* be the number of characteristics in Country *C*1 that is greater than another country called *C*2 (k_{C1}^* is called the lead factor for country *C*1). Similarly, let k_{C2}^* be the number of characteristics in Country *C*2 that is greater than Country *C*1 (k_{C2}^* is called the lead factor for country *C*2).

If $k_{C1}^* > k_{C2}^*$, this implies that Country *C*1 is in a higher stage of development than Country C2. If $k_{C1}^* < k_{C2}^*$, then Country *C*2 is said to be in a higher stage of development than *C*1. The country-ranking criterion also satisfies the transitivity property.

In the case when $k_{C1}^* = k_{C2}^*$, we examine the second order conditions for the country ranking, that is, the percentage difference between the characteristics for the two countries. If the values of the characteristics for Country *C*1 are higher (in percentage) than for Country *C*2, then Country *C*1 is said to be at a higher stage of development and vice-versa. If the percentage differential between the two countries in the respective characteristics is very close, we say that the stages of development in these countries are very similar.

4.4 The Data

In this study, we have used secondary data from several sources. They include the *IMD World Competitiveness Report (1995-2003), Digital Planet 2002: The Global Information Economy, the World Intellectual Property Organization (WIPO) and the United Nations Statistics Database*. The sample size consists of twenty-five countries, representing fourteen developed and eleven developing countries. The sample countries used in this study are as follows:

1. Australia	2. Brazil	3. Canada	4. Chile
5. China	6. Finland	7. Germany	8. India
9. Indonesia	10. Ireland	11. Japan	12. South Korea
13. Malaysia	14. Mexico	15. New Zealand	16. Norway
17. The Philippines	18. Singapore	19. South Africa	20.Sweden
21. Switzerland	22. Taiwan	23. Thailand	24. United Kingdom
25. The United States			

In the previous section, we outlined a broad set of Reach and Rich factors that can be used for capturing the different stages of development in countries. However, one of the difficulties we encountered was getting standardized measured proxies for some of the factors for all the twenty-five countries. In this study, we were able to identify thirty-two factors that measure some of the Reach and Rich characteristics. Below we list these factors.

4.4.1 Reach Factors

In this section, we used thirteen indicators that capture the level and quality of connectivity in the information economy.

1. Number of Internet Users per 1000 people
2. IT Hardware expenditure per capita, US$
3. Software expenditure per capita, US$
4. IT Services expenditure per capita, US$
5. Number of PCs used in the education sector per 1 million people
6. Number of PCs used in home per 1 million people.
7. Number of PCs used in the business and government sectors per 1 million people.
8. Number of telephone lines per household
9. Telecommunication investment per capita, US$
10. Computers per 1000 people
11. Number of mobile telephone users per 1000 people
12. Computer power per 1000 people (*share of total millions instructions per second (MIPS)*) - data for this variable was not available for two years, that is, 1999 and 2001. According to Moore's Law, the speed of computer chip will increase 50 percent in every six months, therefore it is feasible to estimate that the computer power will double every year (Moore, 1965). Thus, the data for the year 1999 and 2001 were calculated based on the following formula:

$$\text{Computer power per capita} = \frac{[\text{computer power per capita of the previous year } x \text{ population}]\ x\ 2}{\text{population of current year}} \qquad (1)$$

13. Distribution systems [3] (*an index of the efficiency of distribution systems in a country*). This is shown as:

$$I_{DS} = \begin{cases} 1 \text{ if the distribution system is less efficient} \\ 10 \text{ if the distribution system is efficient} \end{cases}$$

4.4.2 Intellectual Capital Development Factors

The data that measures the level and quality of the human capital in the country are discussed in this section.

1. Skilled labour (*an index of availability of skilled labour in a country*). This is shown as:

$$I_{SL} = \begin{cases} 1 \text{ if skilled labour is not easily available in a country} \\ 10 \text{ if skilled labour is highly available in a country} \end{cases}$$

2. Science & Education (*an index of science education adequately taught in compulsory schools).* This is shown as:

$$I_{SE} = \begin{cases} 1 \text{ if science education is not adequately thaught in compulsory schools} \\ 10 \text{ if science education is adequately thaught in compulsory schools} \end{cases}$$

3. Entrepreneurship (*an index of entrepreneurship is widespread in the economy*)

$$I_{EN} = \begin{cases} 1 \text{ if entrepreneurship is not not widespread in the country} \\ 10 \text{ if entrepreneurship is not not widespread in the country} \end{cases}$$

4. Public education expenditure per capita, US$ - there were some missing data for this variable, namely for 1997, 1999 and 2001. This was computed using the following formula:

$$\text{Public education expenditure per capita} = \frac{[\text{public education expenditure in \% of GDP x GDP}]}{\text{population}} \qquad (2)$$

5. Qualified engineers (*an index for the number of qualified engineers in a country*). This is shown as:

$$I_{QE} = \begin{cases} 1 \text{ if qualified engineers are not easily available in a country} \\ 10 \text{ if qualified engineers are highly available in a country} \end{cases}$$

6. The educational system (*an index of an educational system that meets the needs of a competitive economy).* This is shown as:

[3] Data for variable 4.4.1 (No. 13), 4.4.2 (No. 1,2,3, 5 and 6), 4.4.3 (No. 5, and 6) and 4.4.4 (No.1 and 2) are taken from a survey that was conducted in the respective countries over the sample period. This consisted of 2,500 respondents from high-ranking senior executives and leaders from the sample countries (for details refer to IMD, 1995-2003).

$$I_{HC} = \begin{cases} 1 \text{ if education is less efficient} \\ 10 \text{ if education is highly efficient in meeting the needs of the competitive economy} \end{cases}$$

4.4.3 Innovation Factors

Innovation in the countries is characterized by the seven factors listed below.[4]

1. R&D personnel in the business sector per 1000 people
2. R&D personnel nationwide per 1000 people
3. Total R&D expenditure per capita, US$
4. Business R&D expenditure per capita, US$
5. Basic Research (*an index of basic research that enhances long term economic and technological development*). This is shown as:

$$I_{BS} = \begin{cases} 1 \text{ if basic research is less available in a country} \\ 10 \text{ if basic research is highly available in a country} \end{cases}$$

6. Patents & Copyrights Protection (*an index of adequately protected intellectual property in a country).*
   This is shown as:

$$I_{BS} = \begin{cases} 1 \text{ if patents \& copyrights are less adequately protected} \\ 10 \text{ if patents \& copyrights are adequately protected} \end{cases}$$

7. Total Patent Productivity per 1000 R&D personnel. This variable was measured using the following formula:

$$\text{Total Patent Productivity} = \frac{\text{Total Patent Granted to Residents}}{\text{Total R\&D Personnel Nationwide}} \text{ x } 1000 \qquad (3)$$

4.4.4 Interaction (Strategic Partnership) Factors

The level of interaction (strategic partnership) is characterized by two factors. They are:

1. Research Cooperation (*research cooperation between companies and universities).* This is shown as:

$$I_{RC} = \begin{cases} 1 \text{ if research cooperation between companies \& universities are insufficient} \\ 10 \text{ if research cooperation between companies \& universities are sufficient} \end{cases}$$

2. Technological Cooperation (*technological cooperation between companies).* This is shown as:

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[4] In the Innovation variables, there were some missing data, namely for the Business R&D expenditure per capita [(Brazil, 1995), (the Philippines, 1995), (Indonesia, 1999) and (United States, 1999)], R&D personnel nationwide per capita [(Brazil, 1999), (the Philippines, 1995), (Indonesia, 1999) and (United States, 1999)], Total R&D expenditure per capita [(the Philippines, 1995)], and Business R&D expenditure per capita [(Indonesia, 1999 & 2001)]. All these data were estimated by taking the average of the previous and recent year.

$$I_{TC} = \begin{cases} 1 \text{ if technological cooperation between companies are lacking} \\ 10 \text{ if technological cooperation between companies are highly developed} \end{cases}$$

4.4.5 Productivity Factors

In this paper, we examined four types of productivity, namely, labour productivity, industry productivity, service productivity and overall productivity. Formulation for the four productivity indicators is given below.

1. *Labour productivity* (*GDP per person employed per hour US$*) - there were some missing data for the Labour productivity variable for India (1995 & 1997) and New Zealand (1995). Hence, we used the following formula to compute the missing data: [5]

$$\text{Labour Productivity} = \frac{\text{real GDP (PPP)}}{\text{total employment x average working hours per year}} \tag{4}$$

2. *Industry productivity* (*related GDP (PPP) per person employed in industry, US$)* - there were some missing data for Industry Productivity for all the countries in 1995 and for New Zealand in 1997. This was computed based on the following formula:

$$Industry\ Productivity = \frac{(real\ GDP\ (PPP)\ \text{x}\ \%\ contribution\ of\ industry\ to\ GDP}{(Total\ employment\ \text{x}\ \%\ of\ labor\ in\ industry)} \tag{5}$$

3. Service productivity (*related GDP (PPP) per person employed in services, US$*) – data for the Service Productivity variable were also missing for all the countries in 1995 and for New Zealand in 1997. Hence, this was computed based on the following formula:

$$Service\ Productivity = \frac{(real\ GDP\ (PPP)\ \text{x}\ \%\ contribution\ of\ service\ to\ GDP}{(Total\ employment\ \text{x}\ \%\ of\ labor\ in\ service\ sector)} \tag{6}$$

4. Overall productivity (*GDP (PPP) per person employed in US$) -* there were some missing data for Overall Productivity variable for India for years 1995 and 1997. The data requires denominator of real GDP and purchasing power parity (PPP) per employee. We employed the following formula to calculate the missing data:

$$Overall\ Productivity = \frac{real\ GDP\ (PPP)}{total\ employment} \tag{7}$$

[5] PPP or Purchasing Power Parity is the rates of currency conversion that controls for the differences in price levels among countries. Real GDP figures were given in billions in the original data source. This was converted to millions by multiplying with 1000.

5. THE EMPIRICAL RESULTS

In this section, we report the results of the band classifications for the data using the empirical model discussed in Section 4. Here, we report the findings for 1995, 1997, 1999 and 2001. Incidences of inter-band and intra-band leapfrogging will be highlighted for the sample periods. Result for the band configurations for the Reach-Rich factors and the productivity indicators are given in the Appendix.

5.1 Band Configurations Based on Reach Factors

The band configurations based on the Reach factors are given in Table 1. From the table, we note that the US was in Band 1 in all the four periods. Sweden and Norway was in Band 3 in 1995. In 1997, both countries leapfrogged to Band 1 and remained in this band in 1999. By 2001, Sweden and Norway moved back to Band 2.

Australia was in Band 3 in 1995. In 1997, Australia moved up to Band 2 and remained in this band in the next two years. Switzerland was positioned in Band 2 in 1995 and 1997. In 1999, Switzerland moved up to Band 1 before moving down again to Band 2 in 2001.

Finland was in Band 3 in 1995 and moved up to Band 2 in 1997. Finland remained in this band in 1999 and 2001. Ireland and South Korea were clustered in Band 4 in 1995 and 1997. By 1999, Ireland moved up to Band 3 and remained in this band in 2001, while South Korea remained in Band 4 in the next two years. We note that Band 1, 2 and 3 are very close to each other in terms of the stages of developments in the latter years.

Singapore was clustered in Band 3 in 1995, but moved up to Band 2 in 1997. Singapore remained in this band in 1999 and 2001. Taiwan was in Band 4 in all the four periods.

The developing countries were grouped in Band 5 in all the selected periods (except for Malaysia). Malaysia was in Band 5 in 1995 and moved up to Band 4 in 1997. In the next two periods (1999 and 2001), Malaysia moved back to Band 5 and became the leader of this group. The Latin American countries (Chile, Mexico and Brazil) and South Africa were clustered higher than the other developing Asian countries (Thailand, the Philippines, China, India and Indonesia) in Band 5 over the sample periods.

We also note that the gap between Band 5 and the other bands have been widening in many of the Reach factors over the period. No intra-band leapfrogging occurred in the Reach factor.

5.2 Band Configurations Based on Intellectual/Human Capital Factors

Band movements based on the intellectual/human capital factors are given in Table 2. The US was in Band 3 in 1995. In 1997, the US leapfrogged to Band 1 and remained in this band in 1999 and 2001. Canada and New Zealand was in Band 3 in 1995 and leapfrogged to Band 1 in 1997. In 1999 and 2001, Canada remained in Band 1. New Zealand however slipped to Band 2 in 1999 and further down to Band 3 in 2001.

Ireland was in Band 4 in 1995 and leapfrogged to Band 1 in 1997. By 1999, Ireland moved down to Band 2 and remained in this band in 2001.

Finland and Sweden was in Band 2 in 1995 before moving up to Band 1 in 1997. In 1999, Sweden slipped to Band 2 while Finland slipped further to Band 3. In 2001, both Sweden and Finland was clustered in Band 2. South Korea was in Band 5 in 1995 and moved up to Band 4 in 1997. In the next three years, South Korea remained in Band 4. Singapore was in Band 4 in 1995 before moving up to Band 3 in 1997. By 1999, Singapore was again in Band 4 and moved up to Band 3 in 2001.

In 1995, Malaysia was in Band 5 and moved up to Band 4 in 1997. For the next three periods, Malaysia remained in this band. Chile, South Africa, Thailand and Brazil were in Band 5 in 1995. In 1997, these countries moved up to Band 4. In 1999, Thailand and Brazil slipped back to Band 5, while Chile and South Africa remained in Band 4. These countries remained in similar cluster in 2001. China, Indonesia, India and the Philippines were in Band 5 in four periods.

5.3 Band Configurations Based on Innovation Factors

Band configurations based on the innovation factors are given in Table 3. Japan and Switzerland was in Band 1 in 1995, 1997 and 1999. By 2001, while Switzerland remained in Band 1, Japan moved down to Band 2.

Sweden and Finland was in Band 2 in 1995. In 1997, both countries moved up to Band 1 and remained in this band in 1999 and 2001. The US was in Band 2 in 1995. From 1997 to 1999, the US moved up to Band 1 and slipped to Band 2 in 2001.

Singapore, the UK, and Australia were in Band 3 in 1995 and moved up to Band 2 in 1997. These countries remained in this band in 1999. In 2001, the three countries moved down to Band 3. Taiwan was in Band 4 in 1995 and moved to Band 3 in 1997. Taiwan remained in Band 3 in 1999 before moving down to Band 4 in 2001. South Korea was in Band 3 in 1995 and moved up Band 2 in 1997. By 1999, South Korea slipped to Band 4 and remained in this band in 2001.

Most developing countries were in Band 5 in all the four periods. South Africa, Chile, and Malaysia were in Band 5 in 1995. These countries were clustered in Band 4 in 1997. By 1999, these countries moved back to Band 5 and remained in this band in 2001.

The empirical analysis also showed that the innovation gap between Band 5 and the other bands have been increasing over the sample period. We observe intra-band leapfrogging in this factor - Brazil leapfrogged from seventh position of Band 5 in 1999 to fifth position in 2001.

5.4 Band Configurations Based on Interaction Factors

Table 4 provides the band configurations for the Interaction (Strategic Cooperation) factors. Finland was in Band 1 in all the four periods.

Sweden, the US, and Singapore were in Band 1 in 1995. From 1997 onwards, these countries were clustered in Band 2. Japan was in Band 1 in 1995 and moved down to Band 2 in 1997. By 1999, Japan was in Band 3 and remained in this band in 2001. Switzerland was in Band 1 in 1995 and 1997. Switzerland moved down to Band 2 in 1999 and 2001.

Canada was in Band 2 in all the four periods. Ireland was in Band 3 in 1995. From 1997 onwards, Ireland was clustered in Band 2.

The developing countries were clustered between Band 3 and Band 5 in all the four periods. South Africa was in Band 3 in 1995. From 1997 onwards, this country was clustered in Band 4. Thailand and China was in Band 3 in 1995. In 1997, Thailand remained in Band 3, while China moved to Band 4. Thailand was clustered in Band 5 in 1999 and 2001, while China was in Band 4 in 1999 and Band 5 in 2001.

Malaysia was in Band 4 in 1995 before moving to Band 3 in 1997. In the next two years, Malaysia was in Band 4. Chile and Brazil was in Band 4 in 1995, before moving down to Band 5 in 1997. In 1999 and 2001, Chile moved up to Band 4. Meanwhile, Brazil moved down from Band 4 in 1999 to Band 5 in 2001. No intra-band leapfrogging was observed for this factor.

5.5 Band Configuration Based on Productivity Factors

The band clustering based on the productivity indicators is given in Table 5. Switzerland and Japan were clustered in Band 1 in 1995. Both countries were clustered in Band 2 in the next three periods. Finland and the US were clustered in Band 1 in 1995. In the next three periods, Finland slipped to Band 2, while the US moved to Band 2 in 1997 and 1999, before moving up to Band 1 in 2001. Ireland was in Band 2 in 1995 and moved up to Band 1 in the next three periods.

Australia and Sweden was in Band 3 in 1995. In the next three periods, both countries were clustered in Band 2. Singapore was in Band 3 and Band 2 in 1995 and 1997, respectively. In 1999, Singapore moved to Band 3 and remained in this band in 2001.

South Korea was clustered in Band 4 in 1995 before moving up to Band 3 in 1997. South Korea remained in this band in the remaining periods. Malaysia and Chile were clustered in Band 4 in 1995. In 1997, both countries were clustered in Band 3, before moving to Band 4 in the remaining two periods.

Brazil was in Band 5 in 1995 and moved up to Band 4 in 1997. Brazil remained in this band until 2001. Thailand, which was in Band 4 in 1995 and 1997, moved down to band 5 in 1999, and remained in this band in 2001. China, the Philippines, Indonesia and India were consistently grouped in Band 5 in all the periods. Similar to the earlier patterns, the productivity gap between countries in the lower and upper bands have been widening over the sample period. No intra-band leapfrogging was seen for this factor.

5.6 Summary

From the above analysis, we observed that several countries have experienced inter-band and intra-band leapfrogging in some of the Reach and Rich factors. The empirical analysis showed that Sweden and Norway experienced inter-band leapfrogging in the Reach factors. The analysis also showed that the US, Canada, New Zealand, and Ireland experienced inter-band leapfrogging in the human capital factors. Meanwhile, Brazil experienced intra-band leapfrogging in the innovation factors.

From the above analysis, we also see an emergence of several European countries (such as Ireland, Finland, and Switzerland) that have enhanced their competitive position in the information economy, even surpassing the US and Japan in some of the Reach and Rich indicators. The ASEAN economies (except Singapore) are mostly in the lower bands (low Reach and Rich factors). Other Latin countries (Chile, Mexico and Brazil) and Asian countries with very large population (China, India and Indonesia) are also consistently in the lower bands across all the periods.

The empirical evidence also shows that the gap between countries in the lower bands and countries in the upper bands have been increasing for many of the Reach and Rich factors from 1995 to 2001.

6. STRATEGIES FOR HIGHER STAGES OF DEVELOPMENT & LEAPFROGING: LESSONS FOR DEVELOPING COUNTRIES

From the above empirical analysis, a concerning trend have emerged over the last seven years (1995 – 2001), in that the developing countries have been falling behind the developed countries in terms of the developments in the information economy. In general, most of the countries that have leapfrogged or maintained their positions in the upper bands have implemented strategic and systematic long-term policies to enhance the development of ICT infrastructure, intellectual/human capital, innovation, interaction (strategic partnerships) and institutions in the country. Thus, leapfrogging and sustained growth is a path dependent phenomenon. Countries that fall behind will find it difficult to keep-up with the more developed countries.

In this section, some of the pertinent policies and strategies that were adopted by countries that have leapfrogged, and countries that have maintained their positions in the top three bands (sustained development) over the four periods will be discussed. Lessons from this discussion will be useful in identifying key policies and strategies that developing countries should adopt to 'catch-up' with the more evolved economies.

6.1 ICT Infrastructure Policies

In the upper band countries, both the government and the private sector played a key role in enhancing the ICT infrastructure for the information economy from 1995 to 2001. During this period, funding to upgrade existing ICT infrastructure were borne by both the government and the private sector.

In many of these countries, the telecommunication sectors were liberalized. The intense competition in the telecommunication sector led to three important developments in these countries. First, cost of telecommunication and ICT services reduced significantly. Second, there was a significant growth in the number of fixed telephone line, mobile phone and Internet penetration rates. Lastly, as competition intensified, there was growth in new telecommunication technologies such as broadband and 3G networks in these countries.

The telecommunication industry in the US, especially the Internet, saw a rapid growth over the last decade. Growth in the Internet penetration rate increased the use of computers for personal use and by firms. As more people logged on to the Internet, PC manufacturers and software developers in the US were able to pursue economies of scale. Hence, PC and software prices dropped by almost 30 percent in 1998 (Burrows et al., 1998). The drop in prices further increased the number of Internet users and electronic commerce activities.

The US government also encouraged manufacturers and software companies to develop new technologies to allow higher bandwidth communications across the existing copper network infrastructure. Approximately US$27 billion was spent by the telecommunication sector to build a global broadband network between 1998 and 2002. The US government also invested heavily on fibre-optic cable and other digital communication equipment in the country during this period (US Department of Commerce, 2001). These large capital investments into ICT infrastructure by the government and the private sector have kept the US in the upper bands in the Reach factors.

Meanwhile, Finland has one of the highest numbers of mobile phone users in the world. Finland is one of the earliest countries in the European region to liberalize the telecommunication sector. In 2000, the government provided free 3G mobile licenses to all local telecommunication players (Salminen, 2003). This intensified competition in the telecommunication sector, thus, driving down cost of telecommunication and raising the quality of the ICT service in the country. The opening of the ICT sector have also raised the competitiveness of the Finnish firms – helping Finland to maintain its position in the top three bands for the Reach factors in all the sample periods.

Sweden was consistently placed in the upper bands from 1995 to 2001. This is largely attributed to three major factors. First, Sweden's historical involvement in the telecommunication industry since late 1800s. Sweden is among the early inventors of the telephone system in the world. For example, Lars Magnus Ericsson invented the world's first table phone in 1892. Today, Ericsson has become a major household name in the mobile telecommunication sector.

Second, Sweden is the second country in the European region to deregulate its telecommunication industry. This has helped the country to create a highly competitive telecommunication market in the world. Interestingly, one of the earliest applications of ICT in the financial sector was from Sweden – electronic banking has been used by Swedish banks from 1988.

Third, high investment in ICT infrastructure by the government and the private sector over the last decade has increased the rate of ICT penetration in the country. In 2001, more than 42 percent of the 3.7 million people had access to broadband service in the country (Swedish Institute, 2001). These developments have enabled Sweden to experience inter-band leapfrogging in the mid 1990s.

6.2 Intellectual/Human Capital Development Policies

In an information economy, human capital plays an integral role in enhancing the competitive position and development of a country. Several studies (given in Section 2) have highlighted that human capital is an important factor in assisting smaller and developing countries to catch-up with the more developed economies. Empirical analysis from this study supports earlier studies on the role of human capital development in closing the gap between smaller economies and more evolved economies.

Canada was consistently clustered in the upper bands and even leapfrogged in the intellectual/human capital development factors. Key policies that have helped Canada to be in the top bands are as follows. Public spending on education for all levels (pre-school to tertiary) is very high – second largest public spending after the health care sector in the country. In 2001, public spending on education was around C$58.1 billion (15% of public spending). In 1999, the combined public and private expenditures on educational institutions (all levels of education) as a percentage of GDP was 6.6 percent. This is higher than the OECD countries average of 5.5 percent, and larger developed countries such as the US (6.5 percent), Germany (5.6 percent), UK (5.2 percent) and Japan (4.7 percent).

Further, primary and secondary education is free-of-charge in Canada. The levels of ICT integration in these schools are very high through the 'School-Net Program' (part of the 'Canada Connected Program') funded by the federal government. Canada along with Australia and Finland has the highest proportion of schools (at least 80 percent) that have Internet access. On the other hand, less than 40 percent of the schools in the US have access to the Internet. The PC student ratio in Canada is the second highest with 7 students to a PC, only to be behind Australia (6 students to a PC) in 2000. The OECD average is 34 students to one PC (Statistics Canada, 2003). Thus, the level of literacy and ICT literacy is very high in Canada.

The level of enrolments in post-secondary education in Canada is also high due to various financial incentives and subsidies provided to students enrolled in institutions of higher learning. These incentives can be in the form of government study loan, scholarships and tuition fee-waivers. Further, various programs have been introduced in tertiary institutions to cater for the working population.

The proportion of people in the age category between ages of 25-64 years with either a college or a university credential is 40 percent in 2001. This is the highest among the developed countries. The proportion in the US, Ireland, Japan and Sweden are 37 percent, 36 percent, 34 percent and 32 percent, respectively (Statistics Canada, 2003). The number of individuals aged 25-64 with a tertiary qualification above a bachelor's degree has surpassed 1 million in 2001; this is 7 percent of the working population (Statistics Canada, 2003).

Sweden, a small European country, also placed high importance to human capital development over the years. The number of higher educational institutions in recent years has increased significantly. There are a total of 50 higher educational institutions for a population of 9 million people — per capita investment on education in Sweden is one of the highest among the developed countries (Lindskog et al. 1998). Funding for Swedish universities, especially for postgraduate programs in technology related areas have been on an upward trend. This includes areas such as ICT, biotechnology, material technology and environmental management. Further, education in Sweden is free of charge. This has resulted in increase in university enrollments. First year university enrollments are around 70,000 per year. By 2000, there were a total of 303,100 fulltime students enrolled in the undergraduate and postgraduate programs in Sweden – close to 30% of the young people enrolled in tertiary institutions (Swedish Institute, 2001). These figures are one of the highest among OECD countries.

An important factor that makes Swedish and Canadian tertiary education system highly relevant for the information economy is the strong linkages between universities and the private sector. Thus, the curriculum taught in the universities and polytechnics meet the manpower requirement of the information economy. These institutions of higher learning also have strong links with institutions in other developed and developing countries. The developments in Ireland (that have leapfrogged in this factor) and Finland (in the upper bands in all the sample periods) are very similar to that found in Canada and Sweden.

6.3 Innovation Policies

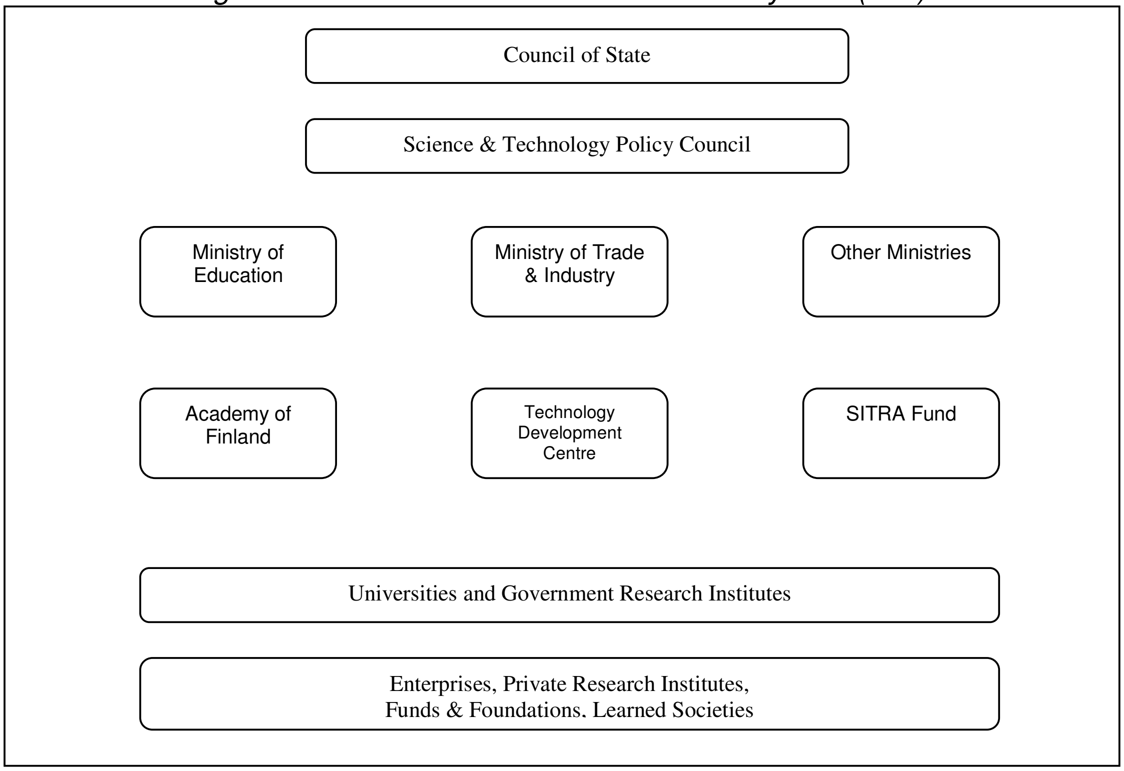
In the new knowledge-based economy, the only constant is 'change' - "*innovation and change are inextricable tied together*" (Porter, 1990). Innovations give firms and nations first-mover advantage, an important factor for sustaining competitive advantage in a rapidly changing environment.

In our empirical analysis, countries that have managed to maintain their positions in the top three bands in the innovation factor is attributed to a focused approach in managing innovation in their countries. In many of the developed countries, a systematic framework (an effective '*National Innovation System*' (NIS)) is in place to effectively manage innovation and R&D in the country. The NIS is referred to as "a collection of institutions that affect the creation, development, commercialization, and adoption of innovation within an economy" (Nelson, 1993).

The NIS also includes organizations and institutions within the country that are responsible for the development of infrastructure, antitrust policy, intellectual property rights and regulatory policy, technology transfer policy, R&D training policy and research education policy. The role of the NIS is also to integrate innovation, ICT, Science and Technology (S&T) policy with other important policies that are related to the economic, social, industrial, political and regional policies. Finland is the first OECD country to adopt the NIS framework for its Science and Technology policy (Ormala, 2001). The structure of the Finnish NIS is given in Figure 5.

Under the NIS framework, many of the countries in the upper bands pursued the *cluster-based development model*, where a cluster is "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter, 1998). In many of the smaller developed countries the clusters were highly focused. For example, some of the important clusters in Switzerland are in the healthcare, textiles, financial services and human resource consulting. In Finland, telecommunication, equipment manufacturing and communication services are vital sectors of the economy. In the case of Ireland, hardware and software sectors are major export earners for the country. Ireland is also a major service hub in the EU for ICT, financial, banking, and pharmaceutical. These above-mentioned clusters in Switzerland, Finland and Ireland are linked with complementing clusters in other developed countries such as the US and other advanced EU countries (strategic cooperation will be discussed in the next section).

Figure 5: The Finnish National Innovation System (NIS)



Source: Ormala (2001)

The cluster framework in the upper band countries has transformed the nature of competitiveness in several ways. First, the focused framework has increase the productivity of the industries in areas these countries have competence. Government, private sector, non-government organizations (NGOs), educational institutions, social groups have a systematic and pragmatic framework to meet the economic and social needs of the country. This approach avoids the duplication of resources, and avoids conflicting directions by the different economic agents to meet the same objective, that is, to enhance the competitiveness of the country.

Second, the pooling of resources and funding for innovation has increased the capacity of innovation in industries in these countries by both the public and private sector. For example, in Finland, there was a significant increase in R&D funding in priority areas for the last decade. Overall, R&D funding increased by 25 percent from 1997 to 1999, raising the national research funding to 2.9 percent of the GDP in 1999 (Ormala, 2001). Private sector contribution to the innovation budget is starting to outstrip government funding by more than 50 percent. Similar pattern can be seen in other smaller European countries (Sweden, and Switzerland), where per-capita R&D investment is closer to the levels of larger economies such as Japan and the US.

Third, there is a large pool of highly skilled research personnel in these countries. This is in part due to the large financial support by government and industry for higher degree research training in universities and research centers. For example, in Finland 25 percent of university research is in the technology related areas. The proportion of students enrolled in technology related programs is around 25 percent. Further, around 13 percent of people in the age group between 18-20 years are enrolled in ICT related fields (Ormala, 2001).

Almost 50 percent of R&D funding in scientific fields in Sweden are channeled to universities for research in 1999. With the increased public and private funding for R&D in universities in these countries, Finland and Sweden have one of the highest number of R&D personnel in the world. From 1999 to 2001, Finland and Sweden had around 9.6 and 7.4 R&D personnel per 1000 workers, respectively. During the same period Japan and the US has around 7.2 and 3.4 R&D personnel per 1000 workers, respectively (IMD, 2003).

Fourth, in many of the countries in the upper bands, various fiscal schemes (tax credits) are in place to enhance innovation among the private sector. Small medium enterprises (SMEs) are major contributors to innovation in the upper band countries. Various active policies and programs are in place to encourage and support innovation amongst the SMEs in these countries. In the US, four major programs have played a key role in encouraging SMEs participation in enhancing innovation in the country. The first program is the known as the *Advanced Technology Program* (ATP), which was introduced under the Bush Administration in 1988 to support high risk and high cost projects.

These projects would normally result in new products, service or processes that would not only benefit the firm, but also the industry and the nation. The funding under this project is for R&D and not for product development. The funds for these projects come from the Federal Government, and the private sector, with the latter contributing more than 50 percent of proceeds for the ATP program (http://www.atp.nist.gov). The ATP awards can be to a single firm or as a joint venture with a consortium of firms, research laboratories and/or universities. To date more than 53 percent of the ATP awards have been given to SMEs (Bozeman and Dietz, 2001).

The second initiative is the *Manufacturing Extension Partnership* (MEP) program, which was highly successful in assisting the SMEs to adopt new and advanced technologies. Under the MEP program, funds are allocated to the various regionally based manufacturing centers and the various extension programs provided by the states. The range of services provided to SMEs includes technical consulting, factory-site reviews, direct hands-on training, technology demonstrations and assistance with selecting the appropriate ICT equipments and software (Coburn, 1995). These training centers are funded by the government via an economic development body or university or a technical college (www.nist.gov).

In 1996, the US General Accounting Office (GAO) study reported that the MEP program had a positive impact on the use of technology in 63 percent of the SMEs, on the quality of the product of 61 percent of the SMEs, and labour productivity of 56 percent of the SMEs. Further, in 1997 a US Census Bureau survey of 4400 firms on the MEP program showed that these firms have increased their revenues by $236 million, and reported a saving of $55 million on labour and material. Upon acquiring the support from the MEP, these firms have invested around $200 million on new technology (www.nist.gov).

A third support program for SMEs in the US is the *Small Business Innovation Research* (SBIR) program. This was started by the National Science Foundation in 1977 with an annual budget of $100 million. Under this program, SMEs are given financial support in innovation and product development. To qualify for this program, firms must be US-owned companies with fewer than 500 employees. Further, these firms must be and independently operated for profit. The SBIR awards are based on the competence of the firms, innovative nature of a proposed project, technical merit of the future market potential (Bozeman and Dietz, 2001).

The SBIR awards has three phases of funding: Phase I – 'Proof of Concept' (support given for exploration based on technical merit and feasibility of an idea or technology); Phase II – 'Pre-Prototype" (commercial potential is evaluated): Phase III – 'Commercialization' (innovation moves from laboratory to marketplace). The latter phase is not funded by SBIR program, but firms are required to seek assistance from other private or non-SBIR funds (www.sba.gov/SBIR/sbir.html). Various programs are in place to assist the SMEs to link-up with other more successful entities (business enterprises, grant award agencies and universities/research centers) for the commercialization phase.

In 1992, the SBIR program was expanded to include other non-profit organisations, research institutions (mostly universities) under a program called the *Small Business Technology Transfer* (STTR) program. The primary objective of STTR program is to transfer technology from the universities/research centers to SMEs for developing commercial products. A 1998 GAO study showed that around 50 percent of the SMEs recorded sales of products or services that was a result of the R&D funding received under the SBIR and STTR programs. The SBIR and STTR programs are very popular amongst the business communities in the US.

Other initiatives to support the creation and adoption of new technology by SMEs in the US include: the *Experimental Program to Stimulate Competitive Research* (EPSCoR), the *State Industry University Cooperative Research Centers* (SIUCRC), tax credit for R&D by the federal and state governments. The EPSCoR and SIUCRC are funded by the National Science Foundation, and details on these programs can be found in www.her.nsf.gov/her/epscor and www.eng.nsf.gov.

The other form of external support that is available to SMEs is venture capital investment. The venture capital funding has three basic financing stages (that is similar to the SBIR awards): *Seed Capital Stage*, *Start-Up Stage* and *Expansion Phase*. Over the period from 1998 to 2001, the US attracted the largest venture capital funding of nearly 0.5 percent of the GDP. Around one third of the funding was given to firms in the start-up phase and near two-thirds in the expansion phase (OECD, 2003). In the US around 50 percent of venture capital, funding is channeled to the ICT sector. In Canada and Ireland, this proportion is higher – more than 60 percent is directed towards innovation in the ICT sector.

In Finland, R&D funding for SMEs is administered through the Technology Development Agency (TEKES). The support comes in the form of R&D grants, capital loans for R&D and Technology Clinics (a consulting service provided to SMEs). In 1999, around 2.3 billion FIM were distributed by TEKES for innovation, of which 75 percent was allocated to SMEs, and remaining to research organizations (universities and research laboratories). Other countries in the upper bands have similar support programs for their SMEs.

In many of the upper band countries, under the NIS, a systematic structure is in place for managing intellectual property rights (IPR). The structure of IPR consists of four main pillars. The first pillar involved raising public awareness of inventions and IPR. Measures on the patenting rules and legal framework to protect IPR are clearly defined, and information of these rules and legislations are effectively communicated to the public. The second pillar includes raising the patent consciousness amongst researchers, university teachers, university administrators, and relevant ministries.

The third pillar consists of promotion of innovations by a scientific technical innovation database. Here researchers and firms can access information on how to patent their innovation, and information on the various scientific breakthroughs that have been patented to date. The fourth pillar is to support SMEs to patent their innovation. In many of the developed countries, the SMEs are charged a lower fee for patenting their first application. The final pillar is to encourage commercialization of patent. Besides registering patents, the patenting office is a one-stop center (like an IP Bank) for other firms to access information on patents that have been commercialized and not commercialized. Access to this information will create a new market for commercialization of patents. This facility assists originators of the innovation to link with firms that are able to take the innovation to the market place.

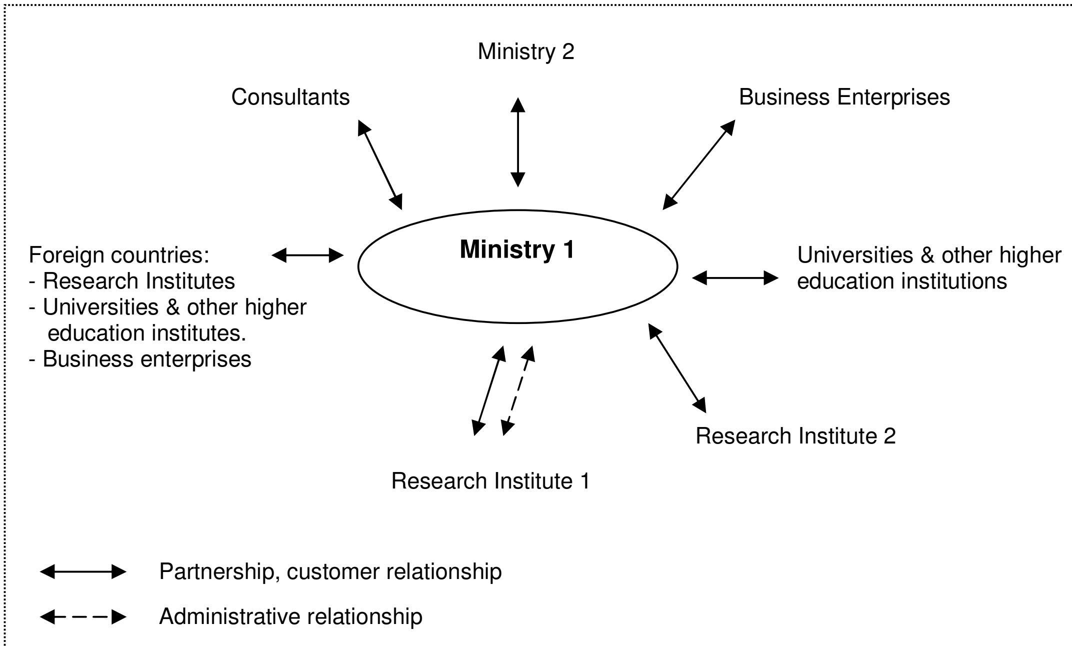
6.5 Interaction Policies

The countries that have leapfrogged and maintained position in higher bands also have strong cooperation and partnerships, especially in the areas of technological and research cooperation. From the empirical analysis, we observe that Finland seems to be in Band 1 in all the four periods. Other smaller countries like Singapore, Ireland, and Switzerland are consistently at the upper bands.

The level of technological and research cooperation in the upper band countries can be attributed to the various support systems and incentives provided for R&D, technology transfer and technological cooperation between firms, research centers, universities and the government organization as discussed in the previous section. The interaction between the economics agents can be characterized from two points of views – the government (ministries) and research organizations (private sectors) (refer to Figure 6 and 7).

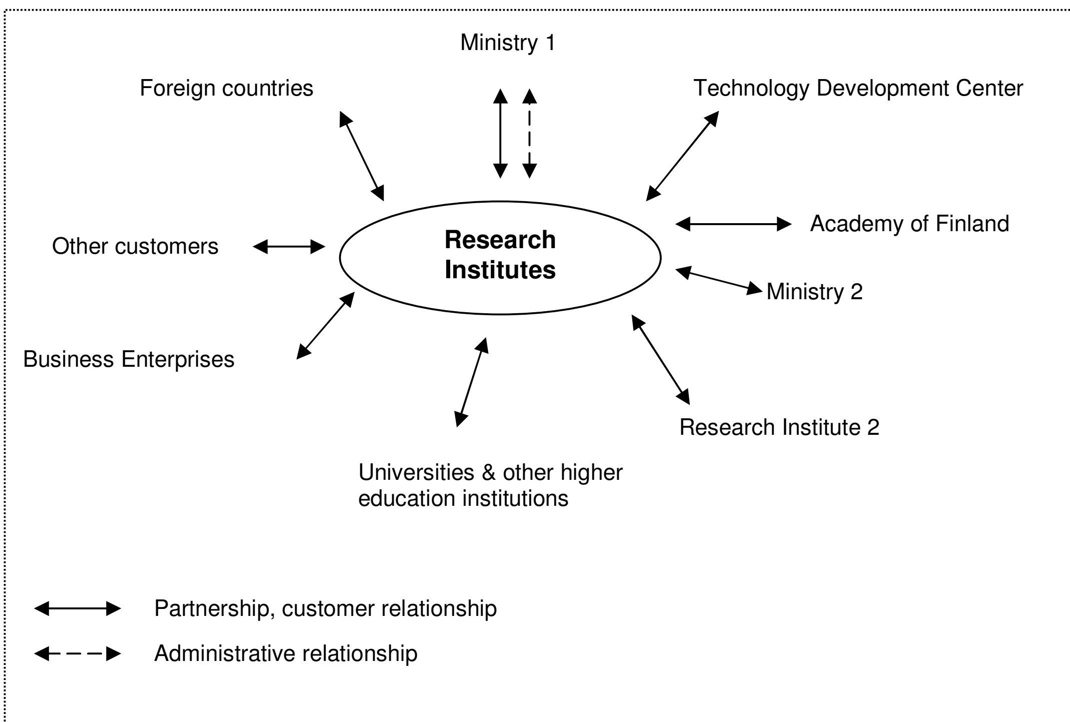
Note that most of the interactions discussed above are among economic agents within the country. There are also significant research and technological cooperation between firms across countries, especially from countries in the upper bands. For example, Nokia, Finland's leading telecommunication has global networks across 54 R&D centers in fourteen countries. This has created job opportunities for nearly 20,000 researchers worldwide. Further, 340 small telecommunication firms were established to spearhead customized research and development activities and be part of the downstream telecommunication sector (Salminen, 2003). Nokia also has established strategic cooperation with local and foreign universities since mid 1990s. For example, Nokia conducted research into speech code standards for GSM, TDMA and 3G systems in collaboration with University of Sherbrooke and VoiceAge Corporation in UK (Jaaski, 2002).

Figure 6: Strategic cooperation from the perspective of government



Source: Ormala (2001)

Figure 7: Strategic cooperation from the perspective of research organizations



Source: Ormala (2001)

Ireland, a country with strong ICT industries, has seen huge inflow of foreign multinationals (MNCs) such as Microsoft and IBM into the country. This has created large ICT based clusters in Ireland with strong links with other similar clusters in the US. Low corporate tax rates, high quality English speaking workforce, strong R&D culture and good ICT infrastructure have contributed to the large flow of FDI's into Ireland in the 1990s.

In 2000, the Irish government and the Massachusetts Institute of Technology (MIT) collaborated to develop the Media Lab Europe - a lab specializing in learning via research in digital technologies. This project involves 50 researchers across both countries, and a total of Euro 2 million per annum was allocated for this purpose (Irish Government Action Plan, 2002).

The strong global interactions/strategic partnerships have enhanced the competitiveness of countries in the upper bands in three major ways. First, it allows domestic firms to access technology and 'know-how' from other countries that have technologies that are more superior. Second, it provides firms' access to cheaper resources (labour, capital, land, and materials) from other countries. Third, the partnerships allow firms to be part of the global network, thus, providing these firms access to a larger market share for their goods and services.

6.6 Summary

From the above discussions, countries that have leapfrogged and maintained their positions in the upper bands had seven major strategies in place. First, there is a systematic framework to manage innovation in the country. All these countries have an effective National Innovation System (which includes important ministries, government organizations, non-governmental organizations (NGO), and the private sector) to formulate policies pertaining to the development of the ICT infrastructure, intellectual/human capital, innovation, interaction/strategic cooperation and institutions to enhance the country's competitiveness in the new economy.

Second, in many of the upper band countries, the economic environment is conducive for sustained growth – these countries have stable social and political climate, sound macro and microeconomic policies, and excellent fiscal incentives for foreign direct investment into the high technology and value-adding sectors of the economy.

Third, liberalization of the ICT sector was an important policy to enhance competition in the upper band countries. This led to an increase in the number of telecommunication operators and ICT service providers in these countries. This has had several positive spillover benefits to firms and consumers in these countries, which included raising the competitiveness of the telecommunication and ICT service providers, lowered cost of ICT services and increased ICT penetration rates.

Fourth, there was high capital investment from the government and private sector in building new ICT infrastructures, and upgrading the old ICT infrastructures. There is also significant investment for the development of new institutions (such as legal framework, quality and rating agencies) that facilitated faster and more effective diffusion of information and knowledge.

Fifth, there is high investment in intellectual/human capital development at all levels (pre-school to tertiary) in the upper band countries. A highly educated population will not only be a source for a high quality workforce, but also creates an advanced consumer market. The latter is important for the development and growth of the value- added goods and service sectors.

Sixth, the level of innovation is high in the upper band countries due to high investment in R&D by the government and the private sector in these countries. Various fiscal and financial incentives are in place to assist SMEs to adopt new technologies, undertake R&D and commercialize their innovation. Other assistance in the form of personnel training and linking up with other business entities and financial granting organizations are available for the SMEs.

Finally, strategic cooperation between the government, the private sector, educational institutions and research centers are strong (both nationally and globally) in upper band countries. This strong partnership has been an important catalyst for smoother and faster technology and knowledge transfer between all the above-mentioned economic agents.

The above discussions serve important lessons for developing countries on the type of policies and strategies that are required to respond to the rapid changes that are taking place globally, and leapfrog in the information economy.

7. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

In this paper, we provide a new empirical framework to capture leapfrogging among countries. The framework does not only capture leapfrogging with respect to technology, but also from the perspectives of human capital development, innovative capabilities and strategic partnership.

Our analysis examined twenty-five countries on thirty-two criterions that are relevant in an information economy for four-selected periods (i.e. 1995, 1997, 1999 and 2001). The empirical findings suggest several important trends emerged over the last decade. First, smaller European countries (such as Finland, Switzerland and Ireland) and Canada have managed to catch-up with Japan and the US (the two economic superpowers in terms of competitiveness and economic development). In some factors, these relatively smaller economies have even managed to surpass the US, Japan, and other larger developed economies. This study also showed that the developing countries are in Band 5 in most of the factors.

In this study, policies and strategies pertaining to the development of ICT infrastructure, intellectual/human capital, innovation, interactions (strategic cooperation) and new institutions in countries that have leapfrogged and are in the upper bands were reviewed. The review of the policies and strategies in the highly competitive economies would be very useful in helping developing countries to formulate policies and strategies that will assist them to 'catch up' with the developed countries.

The empirical results obtained in this study are very preliminary. However, it provides useful insights into the factors and policies that determine the relative competitiveness of countries in the information economy. To improve the current work, research in this area is proceeding in three directions.

First, information on a larger sample of countries than that presented in this paper is being gathered for a wider cross-country comparison. We are also gathering more data on other variables, especially for factors related to intellectual capital, innovation and interaction.

Second, in this paper, we used the K-means clustering algorithm, which used a local search method to classify countries in the respective bands. Thus, the algorithm may not reach a global optima. To overcome this problem, the band classifications were repeated several times until no changes were found in the band configurations. This is to ensure that the algorithm is not trapped in a local optima.

In our future research work, we plan to use the K-means clustering method with a global search method known as the Simulated Annealing optimizing method (Kirkpatrick et al., 1983). This is to avoid the leapfrogging algorithm from being caught in a local optima. One of the major constraints with the simulated annealing search method is that it requires a considerable amount of computing time to get high quality solutions.

Further, the leapfrogging framework in this paper assumed that in each period there are five bands. In a practical setting, this assumption may not hold, as the number of bands may vary in different periods. This entails determining the optimal number of bands in each period. Discussions by Everitt (1979 and 1993) and Nair and Smith (2001) have highlighted some of the difficulties in determining the number of clusters (or bands) in a data set. In practice, heuristic stopping rules are often used to determine the optimal number of clusters within a sample. Future research will explore an appropriate stopping rule to determine optimal band classification for each period.

Third, in this study, we examined the leapfrogging phenomenon at the macro level (national competitiveness level) based on the Reach-Rich factors. There is a lot of scope for studying the leapfrogging phenomenon at the micro level (industry and firm level), and whether there are correlations between the micro and macro level band classifications.

Despite the limitations of the present study, this study provides a good foundation for further research on understanding the key policies and strategies for facilitating leapfrogging in the information economy.

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APPENDIX

Table 1: Band Configuration based on Reach Factors

1995	Band 1	Band 2	Band 3	Band 4	Band 5
	US	Switzerland	Norway	Ireland	Malaysia
			Sweden	Taiwan	Chile
			Finland	Korea	SouthAfrica
			Australia		Mexico
			NewZealand		Brazil
			Singapore		Thailand
			Canada		Philippines
			UK		China
			Germany		India
			Japan		Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	94.50	35.50	35.87	6.75	1.61
X2	399.81	499.29	301.44	127.45	17.41
X3	153.99	243.12	98.41	21.42	4.02
X4	371.13	463.26	226.03	47.76	7.63
X5	777.82	1121.70	683.19	373.26	54.54
X6	22323.10	11364.56	14101.55	5088.11	1218.57
X7	147277.20	120090.24	85567.89	32021.32	2429.88
X8	187011.15	113782.30	106322.55	53546.07	13610.37
X9	0.94	0.90	0.99	1.04	0.25
X10	360.00	197.00	225.50	115.67	22.53
X11	92.70	47.40	89.78	24.80	7.95
X12	11829.97	5839.97	6679.32	3433.66	391.97
X13	8.78	8.32	7.74	5.51	5.00

1997	Band 1	Band 2	Band 3	Band 4	Band 5
	US	Singapore	Japan	Ireland	Chile
	Norway	Australia		Taiwan	SouthAfrica
	Sweden	Switzerland		Korea	Brazil
		Canada		Malaysia	Mexico
		Finland			Thailand
		NewZealand			Philippines
		UK			China
		Germany			India
					Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	251.00	100.15	91.60	25.50	5.87
X2	462.16	337.54	379.07	122.69	19.44
X3	147.91	129.46	84.34	23.51	4.70
X4	401.75	234.50	318.21	42.91	10.06
X5	771.56	779.28	1222.60	386.08	62.21
X6	24326.67	15193.98	11808.76	5376.13	1678.12
X7	163891.98	127085.63	60144.57	39827.99	4645.37
X8	210051.52	151783.52	106909.65	67018.23	15650.00
X9	1.02	0.99	0.96	0.97	0.25
X10	388.67	316.63	228.00	149.75	22.11
X11	315.57	204.10	228.80	99.18	17.32
X12	42428.08	33122.64	23826.08	15465.71	1937.52
X13	8.06	8.12	5.44	6.11	4.85

1999	Band 1	Band 2	Band 3	Band 4	Band 5
	US	Finland	UK	Taiwan	Malaysia
	Sweden	Australia	Japan	Korea	SouthAfrica
	Norway	Singapore	Ireland		Chile
	Switzerland	Canada	Germany		Brazil
		NewZealand			Mexico
					Thailand
					Philippines
					China
					India
					Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	346.97	264.49	185.35	128.87	30.22
X2	544.14	321.47	314.50	123.28	23.27
X3	238.62	132.94	122.05	20.02	6.02
X4	534.24	285.50	288.22	34.32	12.62
X5	877.75	808.78	884.43	377.71	82.89
X6	32744.67	28038.25	13328.28	14617.70	2571.32
X7	232480.98	154453.56	119679.90	54718.76	8352.69
X8	248521.35	203127.32	123996.93	78789.17	27317.65
X9	1.54	1.62	1.39	1.67	0.48
X10	468.62	474.66	343.62	220.70	41.75
X11	493.41	372.17	358.90	496.32	66.78
X12	156291.34	138080.05	102015.08	58265.38	9766.61
X13	7.86	8.24	6.95	5.14	4.63

2001	Band 1	Band 2	Band 3	Band 4	Band 5
	US	Sweden	UK	Taiwan	Malaysia
		Norway	Ireland	Korea	SouthAfrica
		Switzerland			Chile
		Finland			Brazil
		Singapore			Mexico
		Canada			Thailand
		Australia			China
		Japan			Philippines
		NewZealand			India
		Germany			Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	501.50	426.76	281.35	436.05	75.90
X2	477.71	380.24	341.38	160.65	25.57
X3	339.03	193.44	174.11	25.63	6.89
X4	699.45	423.82	316.71	52.38	14.56
X5	933.83	981.13	805.19	423.35	92.27
X6	57312.93	34787.99	23224.25	18309.35	3902.97
X7	284211.40	189235.45	133771.36	95951.47	15037.53
X8	456000.80	247970.98	149700.21	110908.53	38964.70
X9	1.98	1.60	1.51	1.74	0.55
X10	639.00	560.20	476.50	396.50	56.60
X11	435.00	615.24	753.50	744.50	164.50
X12	785046.00	529740.64	442644.73	235536.89	39481.37
X13	7.14	7.55	3.62	5.70	4.42

X1: Internet users per 1000 people
X2: IT hardware expenses per capita, US$
X3: Software expenses per capita, US$
X4: IT Services expenses per capita, US$
X5: Telecommunication investment per capita, US$
X6: PC in education per 1 million people
X7: PC in home per 1 million people
X8: PC in business & government per 1 million people

X9: Number of telephone lines per household
X10: Computer per 1000 people
X11: Mobile phone users per 1000 people
X12: Computer power per 1000 people (MIPS)
X13: Distribution system (efficient)

Table 2: Band Configuration Based on Intellectual/Human Capital Factors

1995	Band 1	Band 2	Band 3	Band 4	Band 5
	Switzerland	Finland	Germany	Australia	Korea
	Norway	Sweden	Japan	Ireland	Malaysia
			US	UK	Brazil
			Canada	Singapore	S.Africa
			N.Zealand	Taiwan	Chile
					Mexico
					Thailand
					Philippines
					India
					Indonesia
					China
	Mean	Mean	Mean	Mean	Mean
X1	6.28	6.57	6.19	6.03	4.98
X2	5.78	5.21	5.05	6.13	4.16
X3	6.38	6.66	6.18	6.42	6.11
X4	2572.40	1910.20	1319.40	888.20	137.90
X5	7.10	5.40	6.70	6.40	4.90
X6	6.14	5.70	5.32	6.31	3.56
	1997				

1997	Band 1	Band 2	Band 3	Band 4	Band 5
	Sweden	Norway	Australia	S.Africa	Philippines
	US		UK	Korea	China
	Canada		Germany	Chile	India
	Finland		Japan	Malaysia	Indonesia
	Switzerland		Singapore	Mexico	
	New Zealand		Taiwan	Brazil	
	Ireland			Thailand	
	Mean	Mean	Mean	Mean	Mean
X1	6.61	6.39	6.38	4.71	5.99
X2	5.68	5.30	6.19	4.94	4.85
X3	6.49	5.54	5.52	6.41	5.44
X4	1462.95	2532.82	962.64	425.82	72.13
X5	6.37	6.70	6.31	5.57	5.41
X6	5.96	5.11	5.49	3.79	4.06

1999	Band 1	Band 2	Band 3	Band 4	Band 5
	US	New Zealand	Norway	Singapore	Thailand
	Canada	Sweden	Finland	South Africa	Philippines
		Switzerland	Germany	Korea	India
		Ireland	UK	Malaysia	Brazil
		Australia	Japan	Mexico	China
			Taiwan	Chile	Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	7.13	6.99	6.57	6.30	6.31
X2	6.26	5.90	6.22	4.93	5.26
X3	6.22	6.29	5.54	5.65	5.61
X4	1343.94	1873.58	804.80	358.33	74.98
X5	7.24	6.64	6.71	6.24	6.58
X6	6.84	5.56	5.06	4.26	4.20

2001	Band 1	Band 2	Band 3	Band 4	Band 5
	US	Norway	Germany	Korea	Thailand
	Canada	Switzerland	New Zealand	Malaysia	Brazil
		Sweden	UK	South Africa	Philippines
		Ireland	Singapore	Chile	India
		Australia	Taiwan	Mexico	China
		Finland	Japan		Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	7.00	6.69	6.76	5.84	6.29
X2	5.11	5.82	5.50	4.49	4.42
X3	6.90	6.44	5.65	5.56	5.37
X4	2457.02	1796.52	1042.33	527.18	119.16
X5	6.62	6.72	6.66	6.45	6.43
X6	5.72	6.61	5.35	3.61	3.99

X1: Skilled labour (availability in a country)
X2: Science & education (adequately taught in schools)
X3: Entrepreneurship (common in a country)
X4: Public education expenses per capita, US$
X5: Qualified engineers (availability in a country)
X6: Education system (competitive education system in a country)

Table 3: Band Configuration Based on Innovation Factors

1995	Band 1	Band 2	Band 3	Band 4	Band 5
	Japan	Sweden	Norway	Taiwan	SouthAfrica
	Switzerland	Finland	UK		Chile
		Germany	Canada		China
		US	Singapore		Malaysia
			Ireland		Brazil
			Korea		Philippines
			Australia		Mexico
			New Zealand		India
					Thailand
					Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	4.71	3.47	1.83	1.80	0.12
X2	7.20	5.56	3.88	3.31	0.50
X3	989.32	677.50	311.47	222.69	11.08
X4	671.95	444.83	179.64	128.16	2.93
X5	6.52	6.43	5.30	5.59	4.05
X6	7.61	7.93	7.34	6.38	4.82
X7	73.17	38.73	21.14	474.75	12.60

1999	Band 1	Band 2	Band 3	Band 4	Band 5
	Switzerland	Norway	Taiwan	Korea	SouthAfrica
	Sweden	UK			China
	Finland	Canada			Malaysia
	US	Singapore			Chile
	Japan	Ireland			Brazil
	Germany	Australia			Mexico
		New Zealand			Thailand
					India
					Philippines
					Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	4.28	1.86	3.16	1.66	0.08
X2	6.64	3.47	4.74	2.74	0.34
X3	923.44	317.82	267.20	214.00	13.78
X4	653.15	180.97	169.87	121.51	4.80
X5	7.47	6.94	5.48	7.28	4.62
X6	8.35	8.08	7.26	4.61	5.59
X7	56.80	17.44	173.08	336.55	8.38

1997	Band 1	Band 2	Band 3	Band 4	Band 5
	Switzerland	Norway	Taiwan	SouthAfrica	China
	Japan	UK		Malaysia	Brazil
	Sweden	Canada		Chile	Philippines
	Finland	Ireland			Mexico
	US	Singapore			India
	Germany	Korea			Thailand
		Australia			Indonesia
		New Zealand			
	Mean	Mean	Mean	Mean	Mean
X1	4.13	1.99	3.01	0.15	0.06
X2	6.18	4.07	4.56	0.47	0.37
X3	857.52	346.75	252.08	17.47	7.34
X4	612.81	208.70	154.86	6.36	1.95
X5	6.38	5.56	5.15	5.11	3.32
X6	7.44	7.07	6.10	5.72	4.39
X7	58.97	31.26	395.15	14.83	5.87

2001	Band 1	Band 2	Band 3	Band 4	Band 5
	Finland	Japan	Germany	Taiwan	China
	Sweden	US	Norway	Korea	Chile
	Switzerland		Canada		South Africa
			UK		Brazil
			Singapore		Malaysia
			Ireland		Mexico
			Australia		India
			New Zealand		Thailand
					Philippines
					Indonesia
	Mean	Mean	Mean	Mean	Mean
X1	5.17	3.64	2.23	2.53	0.12
X2	8.22	5.19	4.20	3.82	0.37
X3	896.74	1053.39	403.95	267.35	11.00
X4	659.09	764.42	244.35	182.32	5.28
X5	7.52	7.43	6.50	6.03	4.47
X6	8.53	8.30	8.32	6.52	5.54
X7	14.81	107.05	23.40	213.12	2.74

X1: R&D personnel in business per 1000 people
X2: R&D personnel nationwide per 1000 people
X3: Total R&D expenses per capita, US$
X4: Business R&D expenses per capita, US$
X5: Basic research
X6: Patents & Copyright protection
X7: Patent productivity per 1000 R&D personnel

Table 4: Band Configuration based on Interaction Factors

1995	Band 1	Band 2	Band 3	Band 4	Band 5
	Finland	Australia	SouthAfrica	Malaysia	Philippines
	Sweden	UK	Ireland	Chile	India
	US	Canada	Thailand	Brazil	Mexico
	Singapore	New Zealand	Korea		Indonesia
	Japan	Norway	China		
	Switzerland				
	Germany				
	Taiwan				
	Mean	Mean	Mean	Mean	Mean
X1	5.71	4.70	4.13	3.38	2.53
X2	5.95	5.27	4.18	4.44	3.42

1997	Band 1	Band 2	Band 3	Band 4	Band 5
	Finland	Norway	Australia	SouthAfrica	Chile
	Switzerland	Singapore	UK	China	Brazil
		New Zealand	Malaysia	Korea	Philippines
		Germany	Thailand		India
		US			Mexico
		Taiwan			Indonesia
		Sweden			
		Canada			
		Japan			
		Ireland			
	Mean	Mean	Mean	Mean	Mean
X1	6.64	5.41	4.48	4.42	3.18
X2	6.38	5.49	4.93	3.71	3.58

1999	Band 1	Band 2	Band 3	Band 4	Band 5
	Finland	Singapore	Japan	Malaysia	Korea
		Sweden		UK	India
		US		China	Mexico
		Canada		SouthAfrica	Thailand
		Switzerland		Philippines	Indonesia
		Germany		Chile	
		Taiwan		Brazil	
		Australia			
		Ireland			
		Norway			
		New Zealand			
	Mean	Mean	Mean	Mean	Mean
X1	6.93	5.21	4.02	3.89	2.73
X2	7.06	5.44	6.07	4.20	3.22

2001	Band 1	Band 2	Band 3	Band 4	Band 5
	Finland	US	Japan	UK	Thailand
		Sweden		New Zealand	Brazil
		Singapore		Norway	India
		Canada		Korea	China
		Ireland		Philippines	Mexico
		Switzerland		SouthAfrica	Indonesia
		Taiwan		Chile	
		Australia		Malaysia	
		Germany			
	Mean	Mean	Mean	Mean	Mean
X1	7.68	5.69	3.60	4.05	2.93
X2	7.70	6.06	6.02	4.58	3.58

X1: Research cooperation
X2: Technological cooperation

Table 5: Band Configuration based on Productivity Factors

1995	Band 1	Band 2	Band 3	Band 4	Band 5
	Switzerland	Ireland	Canada	Korea	Brazil
	Norway		Sweden	Chile	Philippines
	Japan		UK	SouthAfrica	China
	US		Australia	Malaysia	India
	Germany		Singapore	Thailand	Indonesia
	Finland		Taiwan	Mexico	
			New Zealand		
	Mean	Mean	Mean	Mean	Mean
X1	35.74	27.10	21.33	5.39	1.72
X2	57503.34	14934.33	49523.81	33356.92	15347.80
X3	44830.95	68385.28	40786.68	23240.75	8059.99
X4	69539.80	44293.93	41629.45	11721.80	3396.35

1997	Band 1	Band 2	Band 3	Band 4	Band 5
	Ireland	US	New Zealand	Brazil	Philippines
		Norway	Chile	Thailand	China
		Germany	Korea		India
		Finland	SouthAfrica		Indonesia
		Australia	Malaysia		
		Japan	Mexico		
		Canada			
		Singapore			
		Switzerland			
		UK			
		Sweden			
		Taiwan			
	Mean	Mean	Mean	Mean	Mean
X1	29.98	25.89	14.64	5.85	3.08
X2	17895.90	56465.70	41515.91	24489.97	12060.04
X3	79546.83	46419.71	30327.66	20990.87	7576.82
X4	53433.10	48067.54	31094.88	12045.31	6675.37

1999	Band 1	Band 2	Band 3	Band 4	Band 5
	Ireland	US	UK	Chile	Thailand
		Norway	SouthAfrica	Mexico	China
		Australia	Singapore	Malaysia	Philippines
		Germany	Taiwan	Brazil	India
		Canada	New Zealand		Indonesia
		Finland	Korea		
		Switzerland			
		Sweden			
		Japan			
	Mean	Mean	Mean	Mean	Mean
X1	32.56	28.01	19.96	10.16	3.37
X2	19634.14	61080.81	48722.45	30387.62	15402.00
X3	87272.19	47525.64	38887.73	22781.46	10097.07
X4	58020.98	50750.92	40563.74	21580.47	10806.02

2001	Band 1	Band 2	Band 3	Band 4	Band 5
	US	Canada	SouthAfrica	Chile	Thailand
	Ireland	Australia	Singapore	Mexico	Philippines
	Norway	Germany	New Zealand	Malaysia	India
		Finland	Korea	Brazil	China
		Switzerland			Indonesia
		Japan			
		Sweden			
		Taiwan			
		UK			
	Mean	Mean	Mean	Mean	Mean
X1	36.48	29.39	22.23	10.27	4.21
X2	83565.09	56948.96	57661.01	32626.29	19219.63
X3	62180.44	54769.81	40950.98	23066.94	12126.09
X4	66298.86	54006.58	44260.98	22048.72	8825.24

X1: Overall productivity
X2: Labour productivity
X3: Service productivity
X4: Industry productivity

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