TRENDS OF CONVERGENCE AND DIVERGENCE IN THE INFORMATION ECONOMY: LESSONS FOR DEVELOPING COUNTRIES

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ABSTRACT

Over the last decade, uneven developments and growth in information, communication and technology (ICT) infrastructure, human capital and innovation in the developed and developing countries have led to uneven competitive position across these economies. In this paper, we examine the trends pertaining to the above-mentioned indicators for selected developed and developing countries. Results from the empirical analysis showed countries that have invested heavily into ICT infrastructure, human capital and innovation tend to have higher productivity levels. The empirical evidence also showed that the gap between the developed and developing countries have increased over the seven years from 1995 to 2001. This study also examined the type of policies pertaining to the above-mentioned factors in the more developed and highly competitive economies. Results from this empirical analysis will serve as lessons for developing countries to catch-up with the more evolved economies.

Keywords: *convergence and divergence, information age, trends, developing countries.*

1. INTRODUCTION

Over the last decade, the global landscape has undergone major structural changes. Global boundaries have been brought much closer by the rapid diffusion of information communication and technologies (ICT). Utilization of ICT has helped countries to increase efficiency, productivity and economic growth. These benefits are more evident in the developed economies such as the United States, Finland, Sweden and Germany, which have invested heavily in ICT development over the years. These countries are said to be at the forefront of the *'information age'*. In these countries there is an increased pace of social and economic convergence driven largely by recent developments in ICT.

There has been much discussion on the issue of convergence of less developed economies since the classical work of Solow (1956 & 1957). Solow's studies highlighted that the poor and developing countries will converge faster than the developed countries when the capital stock and output are lower than their steady state levels. One of the key assumptions in these studies is that developing countries have equal access to technology and markets as the developed countries. However, several empirical evidence showed that the above assumptions may not hold [for example see studies by: Abramovitz (1986); Baumol (1986); Dowrick and Nguyen (1989); Gruen (1986); Kormendi and Meguire (1985)].

In the early 1990s, interest on the issues of convergence and divergence emerged, motivated largely with the introduction of the endogenous growth theory by Romer (1990). According to this theory, endogenous factors such technological gap and absorptive capability induces convergence among the developing countries. Barro and Sala-i-Martin (1991, 1995) highlighted that convergence between poor and rich countries took place because of higher investment in human capital and technology. More recently, Stiglitz (2003) argued that factors such as human capital development, innovation, infrastructure and level of strategic cooperation between academia, industry and government are important catalyst for developing countries to close the gap with more developed countries. He argued that the strength of the US economy over the last two decades can be attributed to the above mentioned factors.

The primary objective of this study is to examine trends of convergence and divergence in fourteen sample countries from 1995 to 2001 pertaining to infrastructure, human capital, innovation and productivity. Empirical analysis suggests that countries that have invested heavily in infrastructure, human capital and innovation tend to have higher productivity (for labour, service, industry and overall). Important policies and strategies employed by countries that enhanced their competitive position will also be examined. Results from this empirical analysis will provide insights into the type of policies developing economies should pursue to 'catch-up' with the more developed countries. The rest of the paper is organized as follows. In Section 2, we provide a detailed description of the data used in this study and the data sources. In Section 3, we provide the trends for infrastructure, human capital, innovation and productivity indicators over the selected years. The lessons for developing countries are provided in Section 4. Finally, Section 5 provides the concluding remarks and the future research directions.

2. THE DATA

In this study, we have used secondary data from several sources, namely the IMD World Competitiveness Report (1995–2003), World Intellectual Property Organization (WIPO) (1995-2001), Digital Planet 2002: The Global Information Economy and the United Nations Statistics Database. The fourteen sample countries are as follows:

1	United States	6	Japan	11	The Philippines
2	Ireland	7	Singapore	12	Mexico
3	Finland	8	Malaysia	13	Chile
4	South Korea	9	Thailand	14	Brazil
5	Switzerland	10	Indonesia		

Generally, the sample countries are classified into three categories, that is, developed countries, newly industrialized countries and developing countries. The developed countries consist of the US, Ireland, Finland, Switzerland and Japan. Note that these countries are from three continents - North America, Europe and Asia. The newly industrialized countries include South Korea and Singapore. The developing countries consist of Malaysia, Thailand, Indonesia, The Philippines, Mexico, Chile and Brazil. Note that the sample developing countries are from the Latin American and Asian regions. Further, data on ICT indicators were easily available for these countries over the period 1995 to 2001. A total of fourteen variables were used in this study[1]. These variables were selected and grouped into four major categories, that is, ICT infrastructure, human capital, innovation and productivity.

A. ICT Infrastructure

1. Number of Internet Users per 1000 people
2. IT hardware expenditure per capita[2]
3. Software expenditure per capita
4. Telecommunication investment per capita
5. Number of PCs used at home per 1 million people.

[1] Data for variable A (1) is taken from the *United Nations Statistics Database*. Data for variable A (2-5) is taken from the *Digital Planet 2002: The Global Information Economy*. Data for B (1-2), C (1-2) and D (1-4) are taken from the *IMD World Competitiveness Report* (1995 – 2003). Data for C (3) are taken from the *World Intellectual Property Organization (WIPO)* database and *IMD World Competitiveness Yearbook*.

[2] All expenditure and productivity figures are denoted in US$

B. Human Capital

1. Public Education expenditure per capita
2. Educational System that meets the need of a competitive economy. *Data for this category is from a survey that was conducted in the respective countries over the sample period. This consists of nearly 2,500 respondents from high-ranking senior executives and leaders from the sample countries. The index (I_{HC}) is denoted as follows:*

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

C. Innovation

1. R&D personnel nationwide per 1000 people.
2. Total R&D expenditure per capita
3. Patent Productivity per 1000 R&D personnel. This variable was measured by using the following formula:

$$\text{Patent Productivity} = \frac{\text{Total Patent Granted to Residents}}{\text{Total R\&D Personnel Nationwide}} \times 1000 \quad (1)$$

D. Productivity

1. Labour productivity (*GDP (PPP)*[3] *per person employed per hour*). This variable was measured by using the following formula:

$$\text{Labour Productivity} = \frac{\text{real GDP (PPP)}}{\text{total employment} \times \text{average working hours per year}} \quad (2)$$

2. Industry productivity (*related GDP (PPP) per person employed in industry).* This was measured by using the following formula:

$$\text{Industry Productivity} = \frac{\text{(real GDP (PPP)} \times \text{ \% contribution of industry to GDP}}{\text{(Total employment} \times \text{\% of labor in industry)}} \quad (3)$$

[3] *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 source. This was converted to millions by multiplying with 1000.*

3. Service productivity (*related GDP (PPP) per person employed in services*). This variable was measured by using the following formula:

$$\textit{Service Productivity} = \frac{\textit{(real GDP (PPP)} \times \textit{\% contribution of service to GDP}}{\textit{(Total employment} \times \textit{\% of labor in service sector)}} \quad (4)$$

4. Overall productivity (*GDP (PPP) per person employed).* This variable was measured by using the following formula:

$$\textit{Overall Productivity} = \frac{\textit{real GDP (PPP)}}{\textit{total employment}} \quad (5)$$

3. TREND ANALYSIS

3.1 Trends for ICT Infrastructure

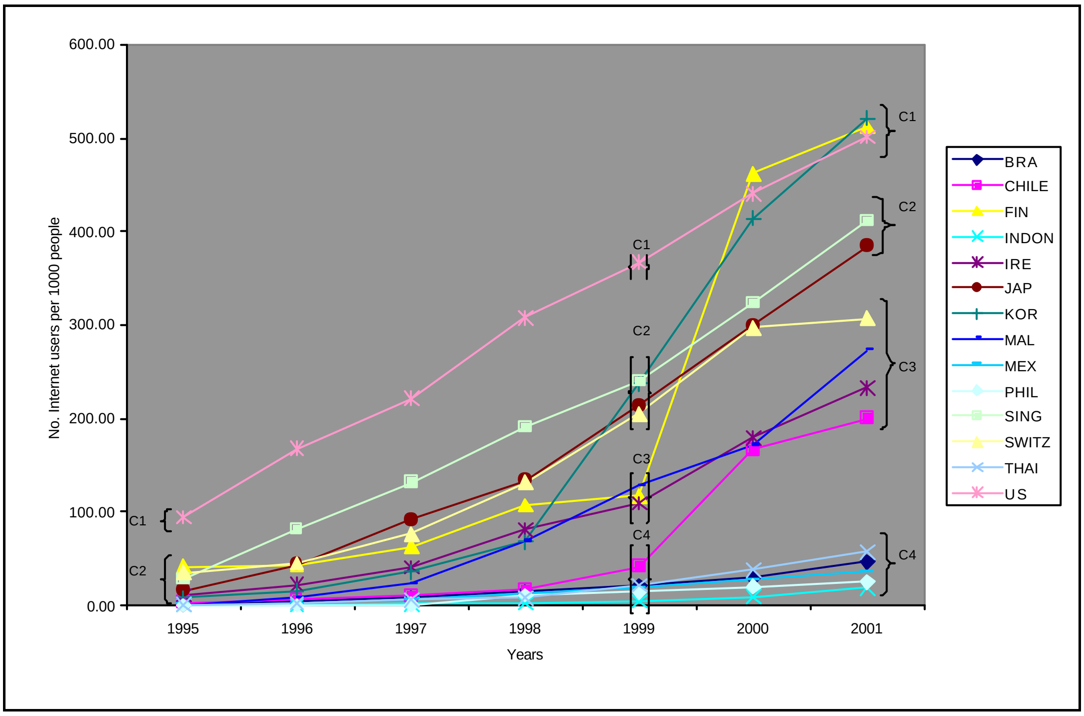
In this section, we will examine the trends pertaining to five ICT infrastructure variables.

3.1.1 Internet Users Per 1000 People

The trend for Internet users is shown in Figure 1. In 1995, we observe formation of two clusters – with the US in Cluster 1 and all the other countries in Cluster 2. By 1999, four major clusters started to emerge. In the US, the Internet penetration rate[4] experienced an increasing trend over the years - the US is the leading country in this variable. We observe that the gap between the US and other countries have been widening from 1995 to 1999. By 2000, South Korea and Finland experienced significant increase in Internet penetration rate. Thus, South Korea and Finland managed to close the digital gap with the US. In fact, Finland overtook leading position of the US in 2000 before being overtaken by South Korea in 2001. In 2001, South Korea, Finland and the US are grouped in Cluster 1 – the countries with the highest number of Internet users per 1000 people. The Internet penetration rate in Singapore and Japan has been on an upward trend over the sample period. Singapore seems to have a higher Internet penetration rate than Japan. By 2001, both countries have diverged from the other sample countries, thus forming Cluster 2.

[4] Internet penetration rate is referred to as the growth in the number of Internet users.

Figure 1: Trends in Internet Users Per 1000 People

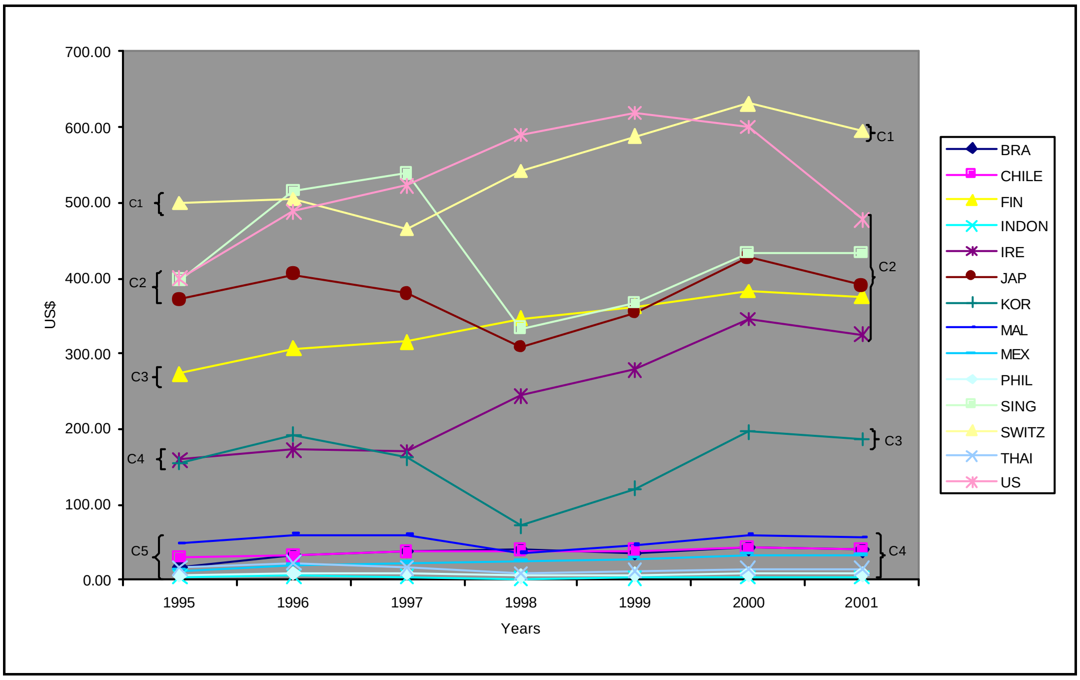


Switzerland's Internet penetration rate was very close to Japan from 1995 to 2000. After 2000, Switzerland's Internet penetration rate fell significantly, thus diverging away from Japan. Malaysia's Internet penetration rate has been increasing sharply over the years. By 2000, the number of Internet users in Malaysia increased higher than Ireland (which was leading before 2000). Chile's Internet user penetration also saw significant growth after 1999. By 2001, Switzerland, Malaysia, Ireland and Chile formed Cluster 3. In Thailand, Brazil, Mexico, the The Philippines and Indonesia (Cluster 4), Internet penetration rate has been growing, albeit at a slower pace compared to other countries in the sample. Note that there exists wide disparity between the developing countries in Cluster 4 and countries in other clusters, especially after 1997.

3.1.2 IT Hardware Expenditure

The trend in IT hardware expenditure in the sample countries is given in Figure 2. The general trend in this variable shows the emergence of five clusters in 1995, that is, Cluster 1 (Switzerland), Cluster 2 (the US, Singapore and Japan), Cluster 3 (Finland), Cluster 4 (Ireland and South Korea) and Cluster 5 (Malaysia, Chile, Brazil, Mexico, Thailand, the Philippines and Indonesia).

Figure 2: Trends in IT Hardware Expenditure Per Capita



Switzerland had the highest IT hardware expenditure per capita in 1995 before plummeting below Singapore and the US in 1996. However by 1997, Switzerland's IT hardware expenditure increased overtaking the US in 2000 - thus forming Cluster 1 in 2001. Note that in 2001, Switzerland saw a decline in IT hardware expenditure. The US, Singapore and Japan were in Cluster 2 in 1995. The US saw continuous increase in IT hardware expenditure per capita from 1995 to 1999. From 2000 onwards, IT hardware expenditure in the US declined significantly. This can be attributed to the slowdown in global IT sector during this period.

Singapore also experienced an upward trend in IT hardware expenditure per capita from 1995 to 1997 period. By 1997, Singapore experienced a significant fall in IT hardware expenditure due to the 1997 Asian Financial Crisis. Note that vast gap started to emerge during this period between Singapore and the US. Nevertheless, by 1999, Singapore's IT hardware expenditure increased due to recovery from the 1997 Asian Financial Crisis by regional economies. This enabled Singapore to converge closer to the US from 1999 onwards. Japan experienced a downward trend in IT hardware expenditure per capita from 1996 to 1998, before moving closer to Singapore and the US by 2001. Ireland's IT hardware expenditure was very much lower than the above-mentioned countries before 1998 (Ireland was in Cluster 4 in 1995).

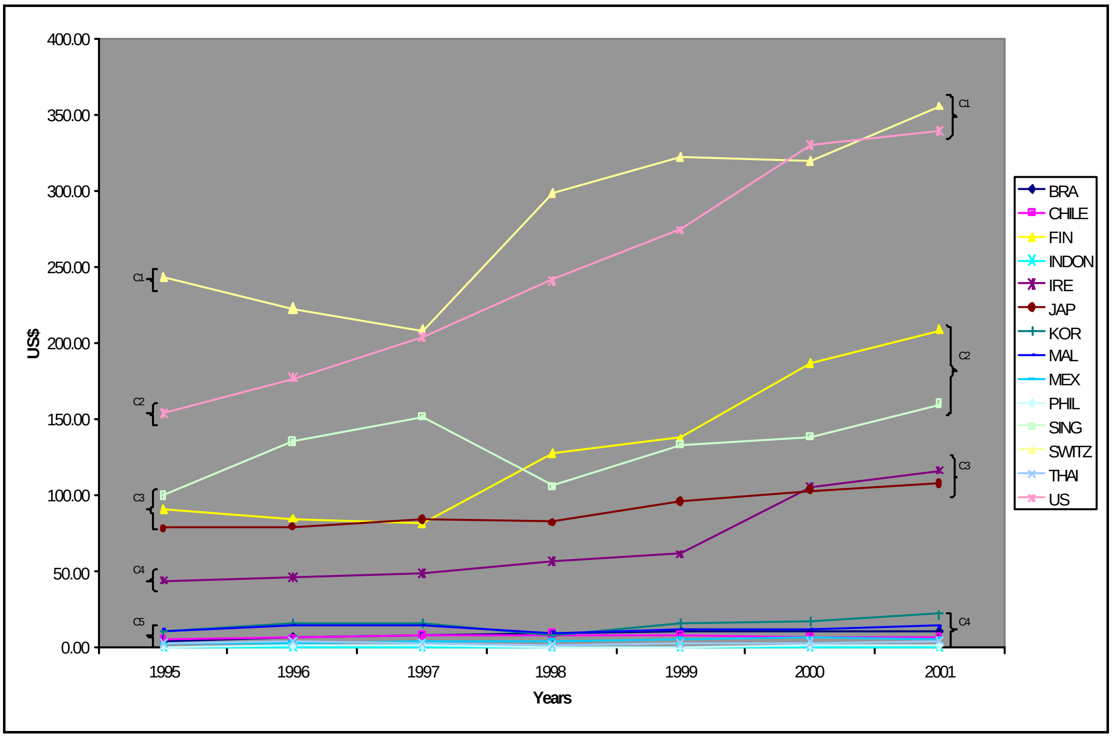
However by 1998, Ireland increased spending on IT hardware per capita significantly converging closer to the US, Singapore, Japan and Finland by 2001. Note that Ireland was in Cluster 2 with the US, Singapore, Japan and Finland in 2001. South Korea, which was in Cluster 4 in 1995, saw significant decline in IT hardware expenditure from 1997 to 1998. South Korea was one of the first countries in the region that were affected by the 1997 Asian Financial Crisis. In the subsequent years, South Korea recovered from the financial crisis and this resulted in an increase in IT hardware expenditure. South Korea was in Cluster 3 in 2001. Developing countries experienced slow growth in IT hardware expenditure per capita over the sample period. Malaysia was leading this group over the years, followed closely by Chile, Brazil and Mexico. By 2001, these countries formed Cluster 4 – the countries with the lowest IT hardware spending. Note the gap between the developed and developing countries have widened over the sample period.

3.1.3 Software Expenditure

The trend for software expenditure per capita is given in Figure 3. In 1995, we observe formation of 5 clusters. Cluster 1 consisted of Switzerland, while Cluster 2 consisted of the US. Finland, Singapore and Japan were in Cluster 3, while Ireland was in Cluster 4. Meanwhile, South Korea, Malaysia, Mexico, Brazil, Chile, Thailand, the Philippines and Indonesia were in Cluster 5.

Switzerland was in Cluster 1 in 1995 – higher than the US and other countries. From 1995 to 1997, Switzerland's software expenditure fell by 15 percent. However, by 1998, the downward trend was reversed and the software expenditure increased, making Switzerland the leading country with the highest software expenditure per capita in 2001. Meanwhile, the US experienced consistent growth in software expenditure per capita over the sample period. By 2001, both Switzerland and the US converged to form Cluster 1. In 1997, Finland saw significant increase in software expenditure. This expenditure grew even higher after 1999. By 1999, Finland's software expenditure was higher than Singapore by 25 percent. Singapore also had seen increasing upward trend in software expenditure from 1995 to 1997. However, significant fall was seen from 1997 to 1998. From 1998 onwards, Singapore experienced continuous increase in software expenditure. Note that the software expenditure for Finland and Singapore were close in 1999. However, the software expenditure diverged from 2000 onwards. In 2001, Finland and Singapore are in the same cluster, that is, Cluster 2.

Figure 3: Trends in Software Expenditure Per Capita



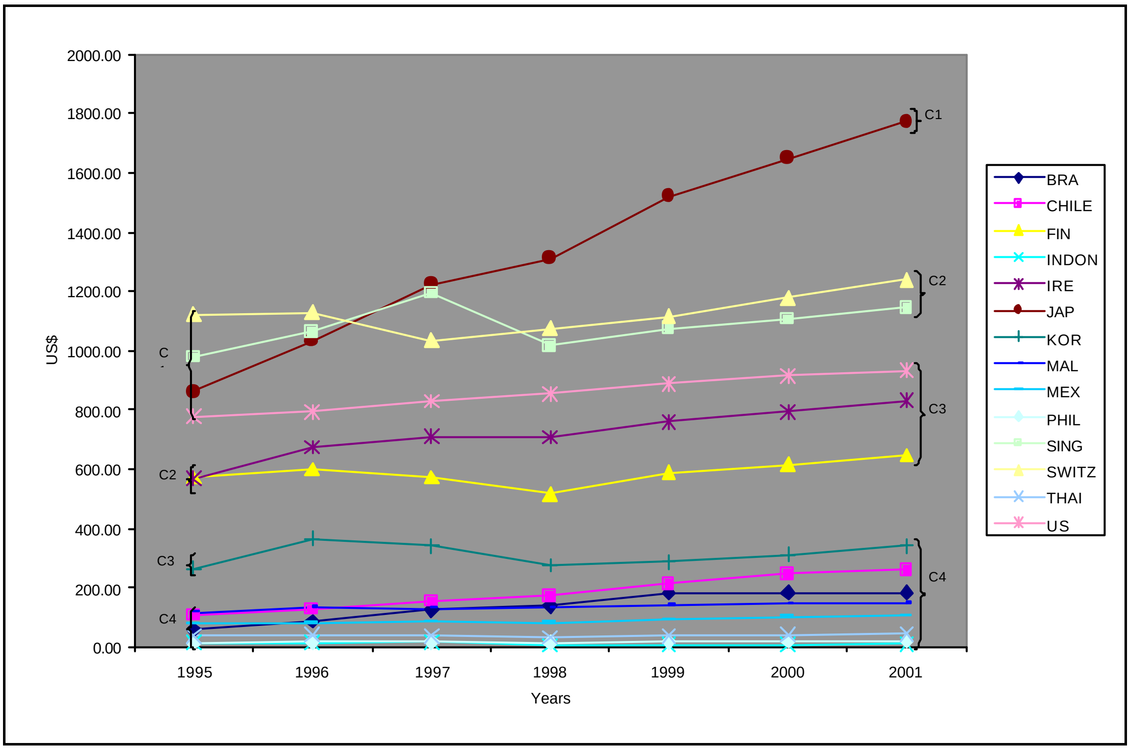
We also note the wide gap between Cluster 2 and Cluster 1 countries have widened after 1997. Ireland and Japan's software expenditure has been growing over the sample period. Ireland experienced consistent growth in software expenditure from 1995 to 1999. Significant rise was seen after 1999 with Ireland overtaking Japan. In 2001, both countries were grouped in Cluster 3.

South Korea and the developing countries (Malaysia, The Philippines, Indonesia, Thailand, Mexico, Brazil and Chile) seem to have very low software expenditure per capita over the years. South Korea is leading this group of countries, although Malaysia was leading prior to 1998. Almost all the countries experienced slight dip in software expenditure during 1997 – 1998 period. In 2001, these countries were grouped in Cluster 4 – the countries with the lowest software expenditure per capita. In fact, the gap between countries in Cluster 4 and countries in other clusters have been widening over the years.

3.1.4 Telecommunication Investment

The trend for telecommunication investment is given in Figure 4. We observe emergence of four clusters in 1995. Japan, Switzerland, Singapore and the US form Cluster 1.

Figure 4: Trends in Telecommunication Investment Per Capita



Ireland and Finland is in Cluster 2, while South Korea is in Cluster 3 in 1995. Chile, Brazil, Malaysia, Mexico, Thailand, the Philippines and Indonesia form Cluster 4 in this year. Japan's telecommunication investment per capita was initially lower than Switzerland and Singapore during the first two years. However by 1997, Japan saw steady growth in telecommunication investment and started to diverge from other countries. By 2001, Japan took the leading position in Cluster 1, with significant gap vis-à-vis other sample countries.

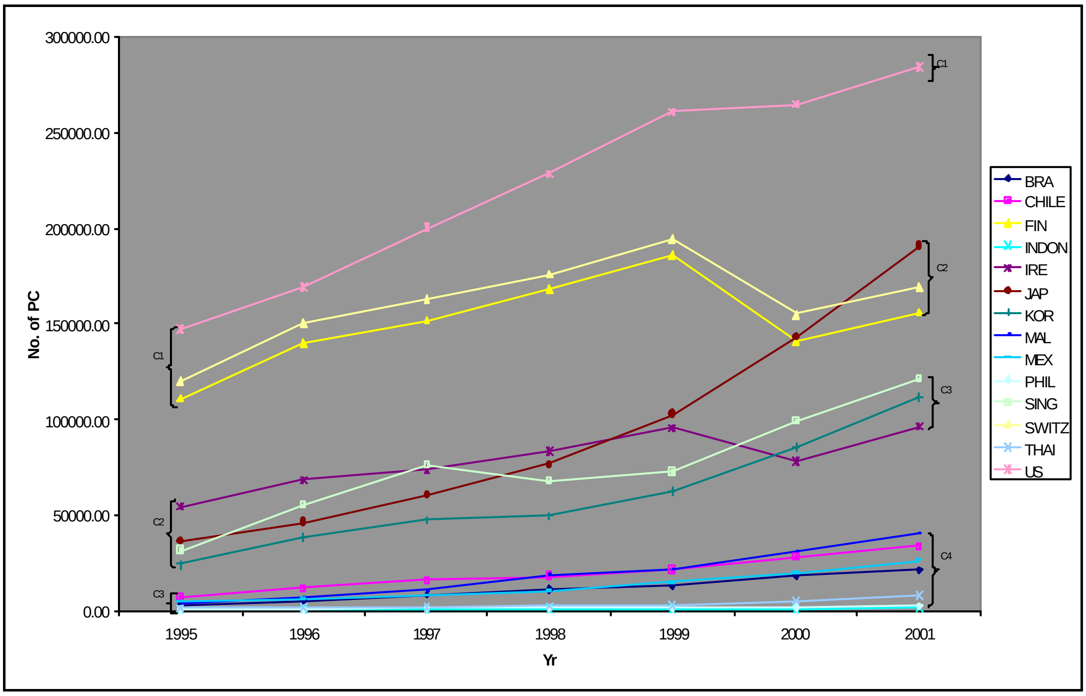
Switzerland's telecommunication investment has increased from 1995 to 1996 before recording a slight decline in 1997. By 1998, the telecommunication investment per capita has increased again and by 2001, Switzerland is the second country with the highest telecommunication investment. Singapore, on the other hand, saw significant increase in telecommunication investment per capita from 1995 to 1997 before a downfall in 1998. By 1999 however, we observe considerable increase in the telecommunication investment – thus positioned Singapore second to Switzerland. In 2001, these countries were grouped in Cluster 2. The US saw consistent growth in telecommunication investment per capita over the sample period. Ireland also saw constant increase in this variable, albeit lower than the US. Finland had the same starting base as Ireland in 1995. From 1996 to 1998 there was slight dip in telecommunication investment per capita in Finland. This trend was reversed in 1998.

By 2001, the US, Ireland and Finland formed Cluster 3. South Korea's telecommunication investment per capita was lower than the above-mentioned countries over the sample period. Except for a slight decline in 1998, South Korea's telecommunication investment has been growing steadily. Among the developing countries, Chile seems to be leading in telecommunication investment. This is followed closely by Brazil, Malaysia and Mexico. Thailand, the Philippines and Indonesia seem to have the lowest investment in telecommunication. The developing countries forms Cluster 4 by 2001 – countries with significantly lower telecommunication investment per capita than the developed countries.

3.1.5 Number of PCs at Home

The trend for the number of PCs at home per 1 million people is given in Figure 5. Three clusters were formed in 1995 – Cluster 1 (the US), Cluster 2 (Japan, Switzerland, Finland, Singapore, South Korea and Ireland) and Cluster 3 (Malaysia, Chile, Mexico, Brazil, Thailand, the Philippines and Indonesia). By 2000, we observe the emergence of four clusters.

Figure 5: Trends in Number of PC in Home Per 1 million people



From Figure 5, we note that the US had the largest number of PCs at home per 1 million people over the sample study period, with significant growth seen after 1996. Further, the gap between the US and other countries have been widening in the later years.

In 2001, the US were grouped in Cluster 1 – the country with the highest number of PCs at home per 1 million people. Meanwhile, Japan (which was in Cluster 2 in 1995) experienced consistent growth in the number of PC ownership in the country. By 2000, Japan overtook Switzerland and Finland in home PC penetration rate and became the leading country in Cluster 2.

Note that Switzerland and Finland experienced very similar growth pattern over the years. From 1995 to 1999, both countries had seen increasing growth in PC ownership before falling significantly from 1999 to 2000. In 2001, both Switzerland and Finland experienced an increase in the number of PCs at home per 1 million people, joining Japan in Cluster 2. Singapore, South Korea and Ireland were in Cluster 2 in 1995. These countries saw consistent growth in PC home penetration rate, although Singapore and Ireland experienced a marginal decrease in 1997 and 1999, respectively. Apart from that, the number of PCs at home in these countries has grown steadily over the years. By 2001, these countries were grouped in Cluster 3. The developing countries also experienced a growth in the home PC penetration rates. However, the growth has been significantly lower than countries in other clusters. Chile was the leader in this group from 1995 to 1998. By 1999, Malaysia replaced Chile as the leader among the developing countries in home PC penetration rate.

3.1.6 Summary

From the above analysis, we observe that the sample countries can be classified into time series clusters for all the ICT infrastructure factors, with Cluster 1 having the highest stage of development, followed by Cluster 2 and so on. We also note that in all these factors, the gap between developed and developing countries seem to be widening over the sample period.

From the empirical evidence, we note that there has been significant increase in investments to upgrade the ICT infrastructure for countries in upper clusters (Cluster 1 and 2). Smaller European economies seem to invest heavily in ICT infrastructure. For example, in 2001, Switzerland invested more in software and hardware than the US and Japan. In the case of Finland and Ireland, the telecommunication sector is highly competitive. These countries are among the most computerized countries in Europe. Finland has nearly 140 telecommunication operators for a population of 6 million (Salminen, 2003).

On the other hand, Ireland is regarded as a leading ICT service hub in Europe. Ireland also benefited from being member of the EU receiving grant of €200 million for infrastructure development in the country (Irish Government Action Plan, 2002). South Korea seems to be making significant progress in enhancing Internet and PC home penetration rates. Besides Japan, South Korea has the most developed telecommunication infrastructure in Asia. In 2001, South Korea connected 144 major cities with high-speed fibre optics (Yang, 2002). In terms of innovation, South Korea is also among the world leaders in code division multiple access (CDMA) technology, with SK Telecom being the world's largest CDMA operator, especially in the mobile phone technology (Dahlman and Anderson, 2000). Developing countries seems to have very low ICT infrastructure development in all the sample periods.

3.2 Trends in Human Capital Development

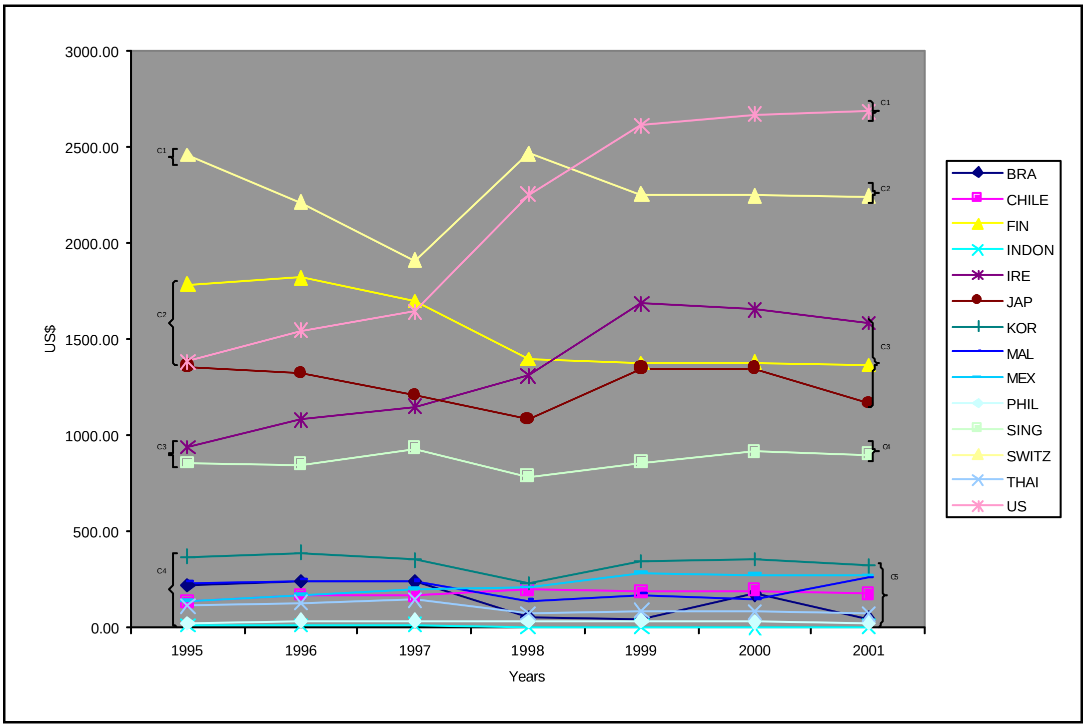
In the new economy, human capital is vital to determine the competitiveness of any economy. In this section, we will examine two important factors pertaining to the human capital in the sample countries – that is, public education expenditure per capita and the relevance of the educational system in meeting the needs of a competitive economy.

3.2.1 Public Education Expenditure

The trend for public education expenditure is given in Figure 6. In this variable, we observe formation of four major clusters in 1995 – Cluster 1 (Switzerland), Cluster 2 (the US, Finland and Japan), Cluster 3 (Ireland and Singapore) and Cluster 4 (South Korea, Mexico, Malaysia, Chile, Thailand, Brazil, the Philippines and Indonesia). From 1995 to 1997, the US had consistently increased its expenditure on public education per capita. From 1998 to 1999, the public education expenditure per capita increased significantly before tapering off. In 2001, the US had the highest public education expenditure per capita – Cluster 1. Switzerland had experienced decline in public education expenditure from 1995 to 1997. By 1997, Switzerland has increased its public education expenditure before experiencing another fall after 1998. In 2001, Switzerland was the second country with the highest expenditure on public education – Cluster 2.

Ireland experienced growth in public education expenditure from 1995 to 1999. By 2001, Ireland's public education expenditure per capita was the third highest in the sample. Finland's public education expenditure was higher than Ireland's from 1995 to 1997. However, Finland experienced a downfall from 1996 onwards. In 2001, Finland's public education expenditure was below Ireland's. Japan also experienced a consistent downfall for the first four years before a gradual increase after 1998. However, another small dip was seen in 2000. By 2001, Ireland, Finland and Japan were grouped in Cluster 3.

Figure 6: Trends in Public Education Expenditure Per Capita



Singapore's public education expenditure was significantly lower than the other developed countries, but much higher than the developing countries. The growth pattern in public education expenditure was steady in the entire sample period except for a small dip in 1997 – 1998 periods. Singapore was in Cluster 4 in 2001 behind Japan (which was in Cluster 3). South Korea was clustered Cluster 5 in 1995. South Korea experienced consistent growth in public education expenditure in almost all the years. However, a small dip was seen in 1997. In the subsequent years, South Korea's public education expenditure increased marginally. By 2001, South Korea was still clustered in Cluster 5.

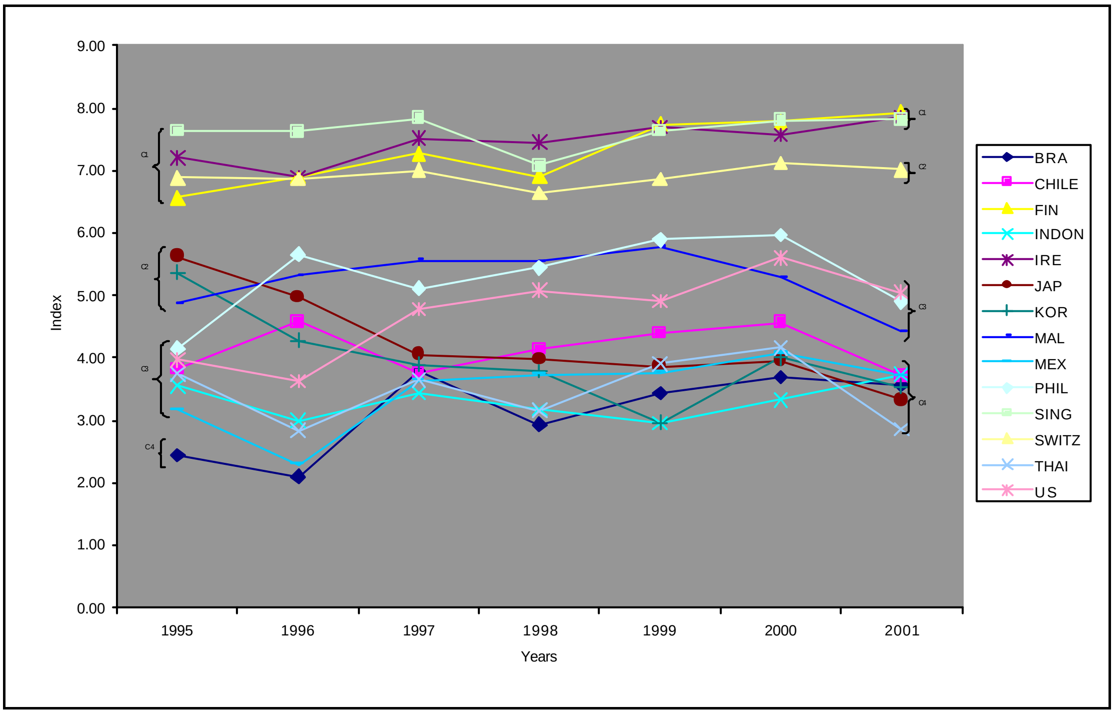
Developing countries had very low public education expenditure per capita as compared to the developed countries. These countries formed the other members of Cluster 5 (together with South Korea) in all the sample years. Note that Mexico, Malaysia and Chile, experienced increase in the public education expenditure from 1998 onwards. Thailand, Brazil, the Philippines and Indonesia seem to be clustered at the bottom of Cluster 5.

3.2.2 Educational System in a Competitive Economy

In this section, we examined whether the education system in the respective countries meets the need for a competitive economy. The trend for this educational index is given in Figure 7. In 1995, we observe emergence of four clusters – Cluster 1 (Singapore, Ireland, Switzerland

and Finland), Cluster 2 (Japan, South Korea and Malaysia), Cluster 3 (the Philippines, the US, Chile, Thailand, Indonesia and Mexico) and Cluster 4 (Brazil).

Figure 7: Trends in Educational System in a Competitive Economy



Starting from a low base in Cluster 1 in 1995, Finland saw consistent increase in the competitive educational index over the study period. By 2001, Finland emerged as the leading country in Cluster 1. Meanwhile, Ireland also saw consistent increase in the competitive educational index over the years, except in 1999. In this year, Ireland's competitive educational index saw a minor decline, before an increase in 2000.

From 1995 to 1997, Singapore had the highest level on the competitive educational index among countries in Cluster 1. In 1998, Singapore's competitive educational index fell, however, this trend was reversed by 1999. In 2001, Finland, Ireland and Singapore converged to Cluster 1, as the countries with the most efficient educational system that meets the need of the new economy. Note that Switzerland was in Cluster 1 in 1995 and experienced no significant change in the competitive educational index over the sample period.
In 2001, Switzerland diverged from Singapore, Ireland and Finland to form Cluster 2. The US were in Cluster 3 in 1995. From 1996 onwards, the US saw a consistent increase in the competitive educational index. By 2001, the US became the leader in Cluster 3.

The Philippines also saw a significant increase in the competitive educational index over the sample period – joining the US in Cluster 3 in 2001. Meanwhile, Malaysia's competitive educational index experienced consistent growth from 1995 to 1999 (positioned closer to the US and the Philippines). By 2000, Malaysia diverged slightly from the US and the Philippines. In 2001, Malaysia joined the US and the Philippines in Cluster 3. Note that Japan and South Korea, which were in Cluster 2 in 1995, saw a continuous fall in the competitive educational index from 1995 to 2001. In 2001, Japan and South Korea's competitive educational index was below that of countries in Cluster 3 – South Korea and Japan were in Cluster 4. Chile, Thailand, Indonesia and Mexico were in Cluster 3 in 1995. By 2001, these countries joined Japan and South Korea in Cluster 4. Brazil was in Cluster 4 in 1995 and maintained its position in Cluster 4 in 2001.

3.2.3 Summary

Based on the above analysis, we observe that smaller countries such as Switzerland, Ireland and Finland seemed to have invested heavily in human capital development. For example, with a total population of nearly six million, Finland has twenty universities and twenty-nine polytechnics. In addition, Finland has also integrated ICT into their education system, at all levels (from primary to tertiary). Further, education is provided free of charge for students from seven to sixteen years old. Similar policies can also be found in Ireland, Switzerland and Singapore. In terms of the relevance of the educational system in meeting the need of a competitive economy, again we observe smaller economies such as Finland, Ireland, Switzerland and Singapore leading the way. In these countries, industry consultative groups are common in jointly assisting universities and training institutes in developing courses that are relevant to the needs of a competitive economy (Statistics Finland, 2001).

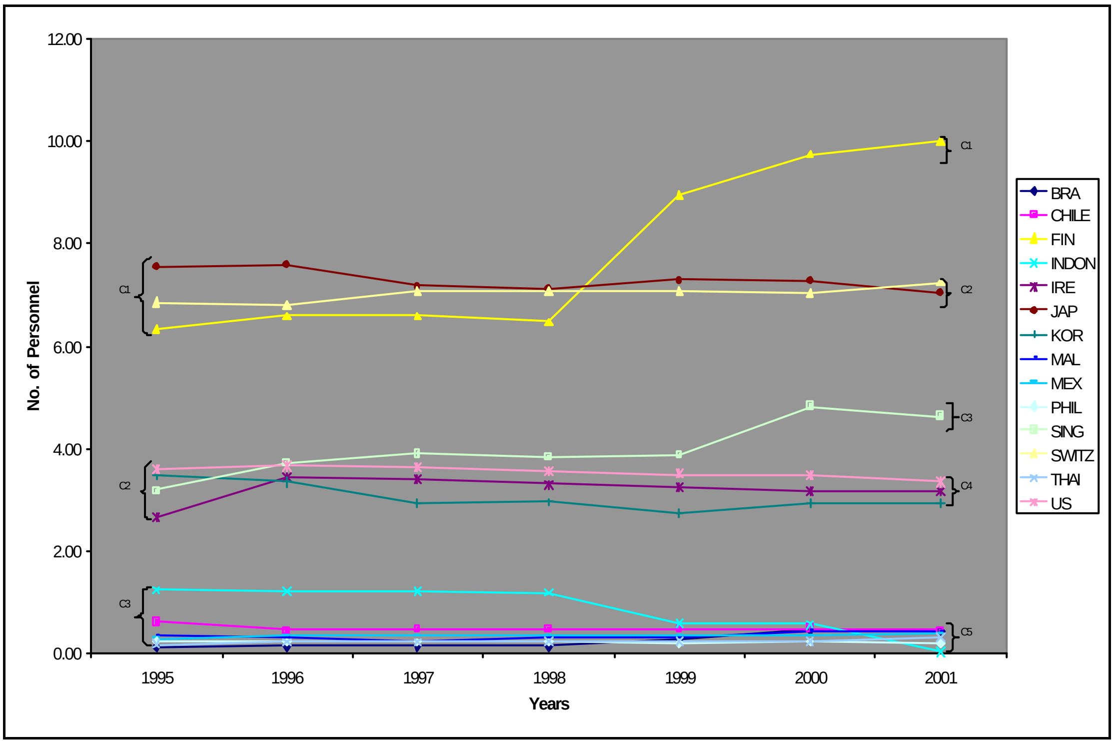
3.3 Trends in Innovation

In this section, we will examine the level of innovation that takes place in the sample countries over the period 1995 to 2001. Here we measure the level of innovation based on three important factors – the number of R&D personnel nationwide, total R&D expenditure per capita and patent productivity per 1000 R&D personnel.

3.3.1 R&D Personnel Nationwide

The trend for the number of R&D personnel nationwide is given in Figure 8. Three clusters emerge in 1995 – Cluster 1 (Japan, Finland and Switzerland), Cluster 2 (Singapore, the US, Ireland and South Korea) and Cluster 3 (Malaysia, Chile, Brazil, Mexico, Thailand, the Philippines and Indonesia).

Figure 8: Trends in R&D Personnel Nationwide Per 1000 People



From Figure 8, we observe that Finland's R&D personnel nationwide increased significantly after 1998. From a country with the lowest number of R&D personnel in Cluster 1 (from 1995 – 1998), Finland saw a significant rise in the number of its R&D personnel from 1999. In fact, Finland overtook Switzerland and Japan in this category after 1999. Note that the gap between Finland and other countries in Cluster 1 (in terms of the number of R&D personnel) increased significantly after 1999. By 2001, Finland was the only country in Cluster 1 - the country with the highest number of R&D personnel nationwide.

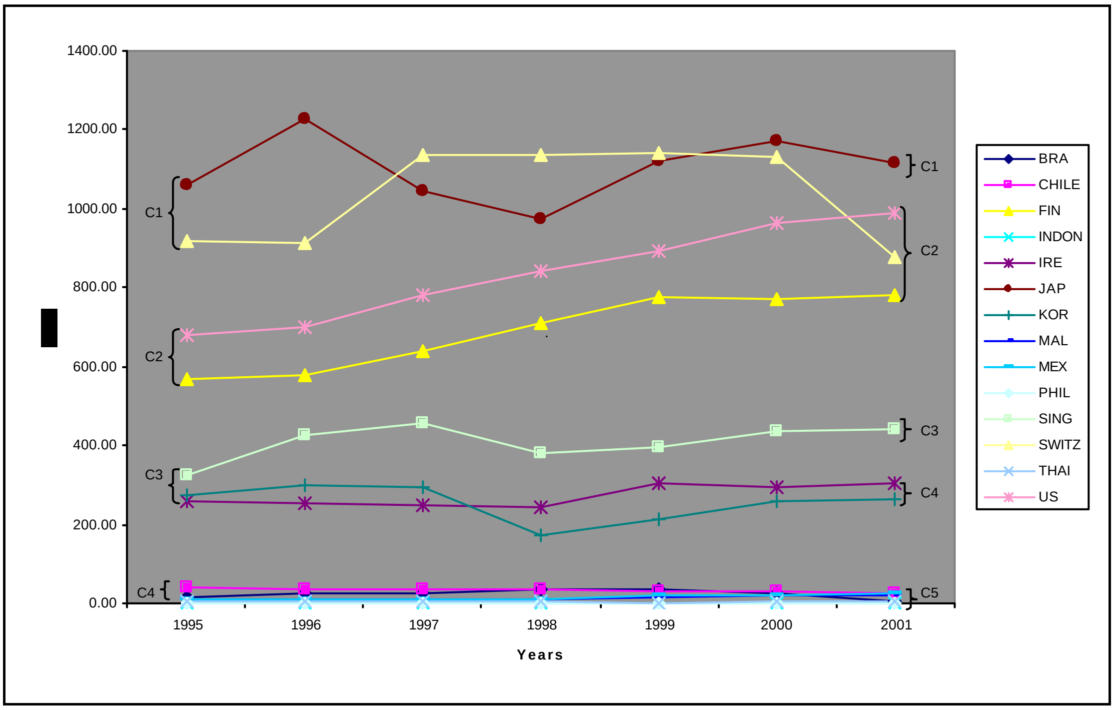
Meanwhile, Switzerland and Japan experienced a gradual increase in the number of R&D personnel nationwide over the years. Note that before 1997, the gap between Switzerland and Japan was wide. By 1998, the number of R&D workers in both Switzerland and Japan seems to have converged, thus forming Cluster 2 in 2001. From 1995 to 1999, we observe that the US, Singapore, Ireland and South Korea were clustered closely.

However, by 2000, the R&D personnel nationwide for Singapore increased significantly – diverging from the US, Ireland and South Korea. The number of R&D personnel nationwide in the developing countries is much lower than in the developed countries. To this end, we observe that the gap between the developed and developing countries have been widening over the years.

3.3.2 Total R&D Expenditure

Figure 9 provides the trend for the total R&D expenditure variable. We observe formation of four clusters in 1995 – Cluster 1 (Japan and Switzerland), Cluster 2 (the US and Finland), Cluster 3 (Singapore, Ireland and South Korea) and Cluster 4 (Mexico, Malaysia, Brazil, Chile, Thailand, the Philippines and Indonesia).

Figure 9: Trends in Total R&D Expenditure Per Capita



Japan's R&D expenditure per capita growth pattern was volatile over the sample period. From 1995 to 1996, Japan saw an increase in the R&D spending before registering a significant downfall from 1996 to 1998. Japan increased its R&D expenditure per capita from 1999 onwards – thus forming Cluster 1 country by 2001. The US experienced a consistent increase in R&D expenditure over the sample period. By 2000, the US overtook Switzerland in R&D expenditure per capita. Meanwhile, Switzerland significantly increased its R&D expenditure per capita from 1995 to 1997.

From 1997 to 2000, Switzerland's R&D expenditure per capita was stagnant and declined slightly in 2001. Finland also experienced similar growth trend as the US from 1995 to 2001. By 2001, the US, Switzerland and Finland were in Cluster 2. Singapore's R&D

expenditure has been at an increasing trend from 1995 to 1997 before falling slightly in 1998. Apart from that, Singapore was the only country in Cluster 3 – the third country with the highest R&D expenditure per capita over the sample period. Ireland and South Korea's R&D expenditure per capita trend has been rather consistent over the sample period. South Korea's R&D expenditure was higher than Ireland from 1995 to 1997. However, significant decline was seen during 1997 to 1998 period. This enabled Ireland to overtake South Korea from 1998 onwards. By 2001, total R&D expenditure in both countries converged, thus forming Cluster 4.

Similar to the earlier variables, the developing countries had the lowest R&D expenditure among the sample countries. Generally, these countries were grouped in Cluster 5, without much significant movement seen over the years in R&D expenditure. The gap between countries in Cluster 5 and other countries had increased over the years.

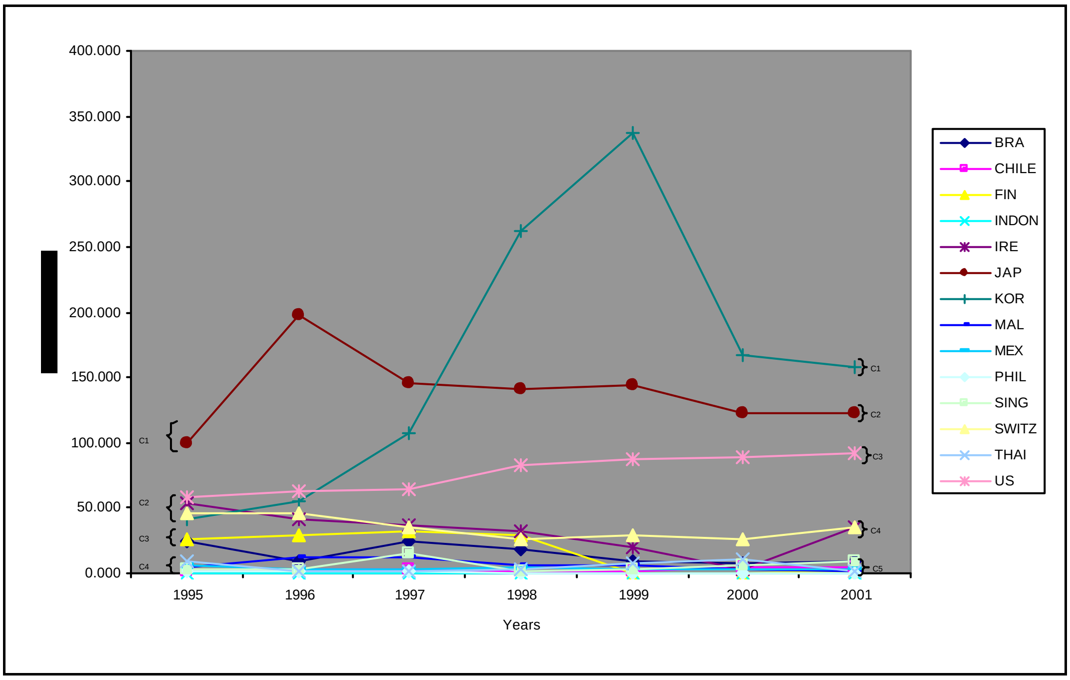
3.3.3 Patent Productivity

Figure 10 shows the trend for patent productivity per 1000 R&D personnel for the fourteen countries. We observe formation of four clusters in 1995 but this evolved to five clusters in the later years. In 1995, Cluster 1 consisted of Japan while Cluster 2 consisted of the US, Ireland, Switzerland and South Korea. Cluster 3 consisted of Finland and Brazil and finally Cluster 4 consisted of Malaysia, Chile, Mexico, Thailand, the Philippines and Indonesia. From 1995 to 1999, South Korea saw a tremendous increase in patent productivity. However by 2000, patent productivity in South Korea decreased significantly. In 2001, South Korea was in Cluster 1 – the country with the highest patent productivity as opposed to other sample countries.

We observe that Japan's patent productivity has been on the rise from 1995 to 1996. However, the patent productivity saw a downtrend from 1996 to 2001. By 2001, Japan was clustered in Cluster 2. The US saw an increase in patent productivity over the years. By 2001, the US was clustered in Cluster 3. Switzerland and Ireland had lower patent productivity compared to other developed countries in the sample. These countries are in fact positioned much closer to the developing countries over the years.

While Switzerland's patent productivity growth was consistent, Ireland experienced a decline in patent productivity in 2000. However, in the following year, Ireland's patent productivity increased again and converged closer to Switzerland. By 2001, both countries were in Cluster 4.

Figure 10: Trends in Patent Productivity Per 1000 R&D Personnel



Finally, we observe that all the developing countries were in Cluster 5 by 2001. Note that Singapore is the leading country in patent productivity in this group. We also observe that slight dip was seen in patent productivity in almost all countries in Cluster 5 from 1997 to 1999 period. On average, these countries had the lowest patent productivity as opposed to the developed countries over the sample period.

3.3.4 Summary

From the above analysis, beside the larger economies (the US and Japan), other smaller countries such as Switzerland, Finland and Ireland have enhanced their innovation and R&D capabilities over the sample period. In Finland, the private sector played a major role in the R&D activities – the electronic industry accounts for two-third of R&D works in the country with substantial contribution made by Nokia. Besides having R&D centers in the country, Nokia also has 52 research centers in nearly 14 countries.

This has helped Finland to increase significantly the number of research and development personnel as well as the number of patents in the country. In Ireland, universities play a key role in R&D activities and some of them are leading research centers in the world. Over the period, the total R&D investment in Ireland increased substantially – in 2001, a total of €2.5 billion was spent in R&D (Irish Government Action Plan, 2002).

An important initiative to spearhead new technology in Ireland was the establishment of a Research Training fund or also known as the Technology Foresight Fund. This fund was established to enhance future new generation technology. Various technological incubators were established to enhance entrepreneurship within the ICT industries. Incentives in the form of tax relief were given to corporation for R&D activities. In Switzerland, the private sector played a key role in enhancing R&D activities. In 1999, 60% of R&D spending was by the private sector. Various center of excellence in the medical and pharmaceutical industries were established in Switzerland. Some of these centers work with other centers from different countries. Some of the Swiss research centers are highly competitive and have extensive global reach.

In Asia, South Korea has been successful in enhancing innovation among its corporations, universities and research centers. Note that over the sample period, patent productivity in South Korea has been on an upward trend. For example, South Korea registered 336 patents per 1000 R&D personnel in 1999. Overall we note that some of the smaller European countries (Finland, Ireland and Switzerland) and a few countries in Asia (Singapore and South Korea) have had a focused approach to increasing the quantum and quality of R&D in their countries. Thus, these countries seem to converge closer to more developed countries such as the US and Japan. On the other hand, investment in R&D and R&D personnel in developing countries – Mexico, Brazil, Chile, Indonesia, the Philippines, Malaysia, Indonesia and Thailand seem to be very low compared to the developed economies. In fact the gap between these countries have been widening over the years.

3.4 Trends in Productivity

Several studies have shown that ICT infrastructure makes cost of communication cheaper, accessing information faster and connecting the world closer [for example, Barro and Sala-i-Martin (1991), Brynjolfsson and Hitt (1995), Broersma and McGuckin (2000), Stiroh (2001) and Colecchia & Schreyer (2002)].

The results from these studies showed that the successful diffusion of ICT does not depend on infrastructure only, but also on the level of absorbability in the country. Thus, education and training are important components for enhancing productivity in the economy. In the new economy, the only constant is change and "innovation and change are inextricably tied together" (Porter, 1990). Thus, countries that enhance their innovative capabilities will also enhance their productivity level. In this section, we examine the trends in four productivity indicators over the sample period. Here, we will examine if the groupings for the productivity is consistent with that for the previous indicators.

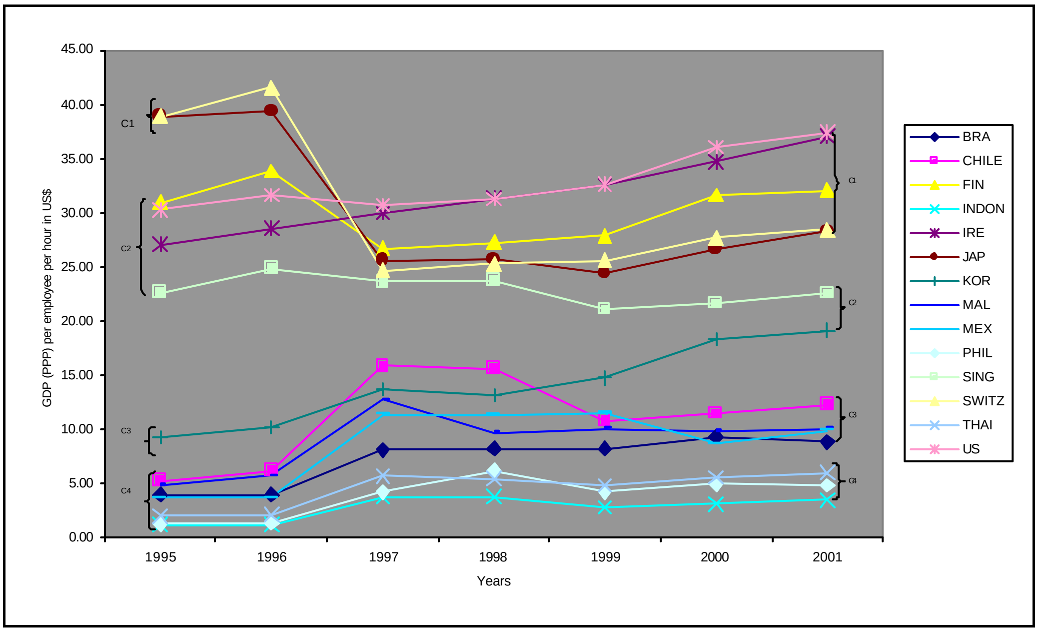
3.4.1 Labour Productivity

Figure 11 shows the trend for labor productivity in all the sample countries. In 1995, we observe formation of four clusters, where Cluster 1 consisted of Switzerland and Japan; Cluster 2 consisted of Finland, the US, Ireland and Singapore; Cluster 3 consisted of South Korea. Cluster 4 consisted of Chile, Malaysia, Brazil, Mexico, Thailand, the Philippines and Indonesia.

In 1997, Switzerland and Japan's labor productivity fell significantly, below the US, Ireland and Finland. From 1997 to 2001, the US, Ireland, Finland, Switzerland and Japan experienced an increase in labor productivity – forming Cluster 1 in 2001. Singapore saw a decline in labor productivity over this period. On the other hand, South Korea saw a significant increase in labor productivity from 1997 to 2001. By 2001, Singapore and South Korea's labor productivity were close – forming Cluster 2.

Developing countries saw a significant increase in labor productivity from 1996 to 1997. From 1998 to 1999, most of the countries saw a decline in labor productivity. In the subsequent years, the labor productivity growth remained low. By 1999, there was a formation of two clusters within the developing countries, in which, Cluster 3 consists of Chile, Malaysia and Brazil, while Cluster 4 consists of Thailand, the Philippines and Indonesia.

Figure 11: Trends in Labour Productivity



3.4.2 Industrial Productivity

The trend for industrial productivity is given in Figure 12. In 1995, we observe the emergence of three major clusters - Cluster 1 (Switzerland, the US, Japan, Singapore, Chile and South Korea), Cluster 2 (Malaysia, Thailand, Indonesia and Mexico) and Cluster 3 (Brazil, the Philippines and Ireland). By 1997, we observe the formation of two major clusters – Cluster 1 consisted of the US, Finland, South Korea, Japan, Switzerland, Singapore and Chile, while Cluster 2 consisted of Malaysia, Mexico, Brazil, Thailand, Indonesia, the Philippines and Ireland.

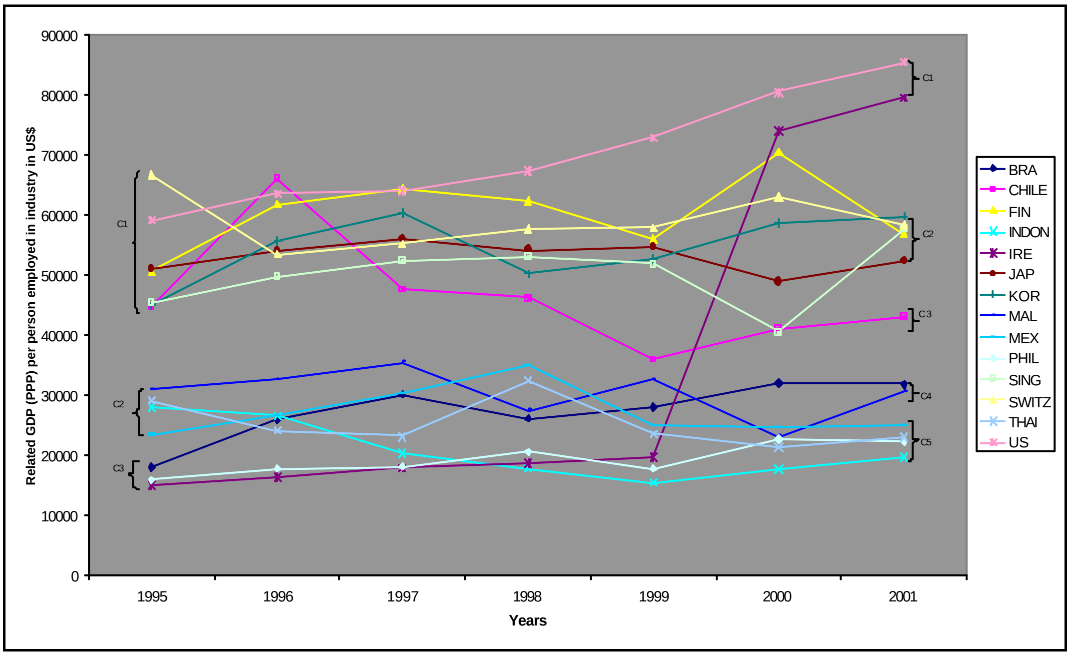
From 1998, we observe that industrial productivity in the US experienced significant growth - diverging from other countries. Ireland also experienced significant increase in industrial productivity, whereby in 2001 Ireland and the US had the highest industrial productivity - forming Cluster 1. South Korea, Switzerland, Finland and Singapore were in Cluster 2 in 2001. The industrial productivity of countries in Cluster 2 was significantly lower than that of countries in Cluster 1.

Chile, which had a high level of industrial productivity in 1996, saw a significant fall in the productivity level from 1996 to 1999. In the subsequent years, Chile saw a moderate increase in industrial productivity level. By 2001, Chile was the only country in Cluster 3. Malaysia, Thailand and Indonesia were in Cluster 3 in 1995. During the sample period, the industrial productivity for Malaysia and Thailand was consistent.

On the other hand, Indonesia's industrial productivity was on a downward trend from 1995 to 1999. By 2000, industrial productivity in Indonesia saw slight increase.

Brazil, the Philippines and Ireland were in Cluster 3 in 1995. However as discussed above, Ireland 'leapfrogged' to Cluster 1 by 2000. Brazil's industrial productivity experienced an upward trend and by 2001, Brazil's industrial productivity ($31,785) was slightly higher than Malaysia's industrial productivity ($30,545) by 4 percent. Note that Brazil and Malaysia were in the same cluster (Cluster 4) in 2001. In 2001, Thailand, Indonesia and the Philippines were placed in Cluster 5 – group with the lowest level of industrial productivity. Note that the industrial productivity for developing countries in 2001 was significantly lower than that in developed countries.

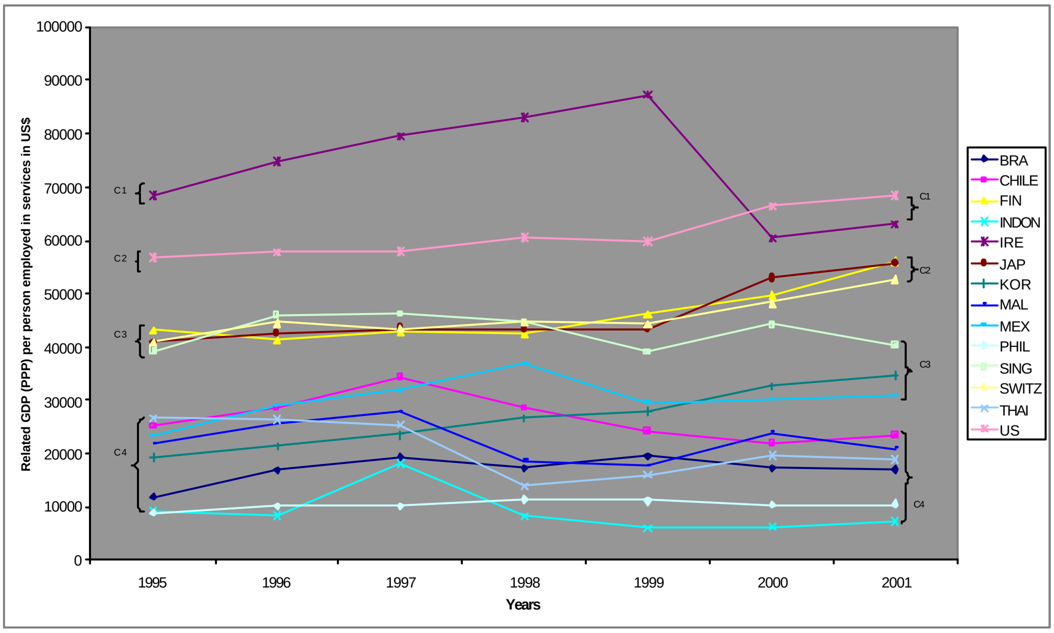
Figure 12: Trends in Industrial Productivity



3.4.3 Service Productivity

Figure 13 shows the trend of service productivity in the sample countries over the seven-year period. In 1995, we observe emergence of four clusters with the US and Ireland in Cluster 1; Japan, Finland and Switzerland in Cluster 2; Singapore, South Korea and Mexico in Cluster 3 and Chile, Malaysia, Thailand and Indonesia in Cluster 4.

Figure 13: Trends in Service Productivity



Ireland experienced an upward trend in service productivity from 1995 to 1999. However in 2000, the service productivity level for Ireland fell significantly by 30 percent. The US on the other hand experienced consistent growth in service productivity from 1995 to 1999. By 2000, service productivity level in the US (which was in Cluster 2 in 1995) increased significantly by 11 percent, thus overtaking Ireland's leading position from 2000 onwards. Note that since the service productivity levels for the US and Ireland were closer in 2000 and 2001, these countries formed Cluster 1.

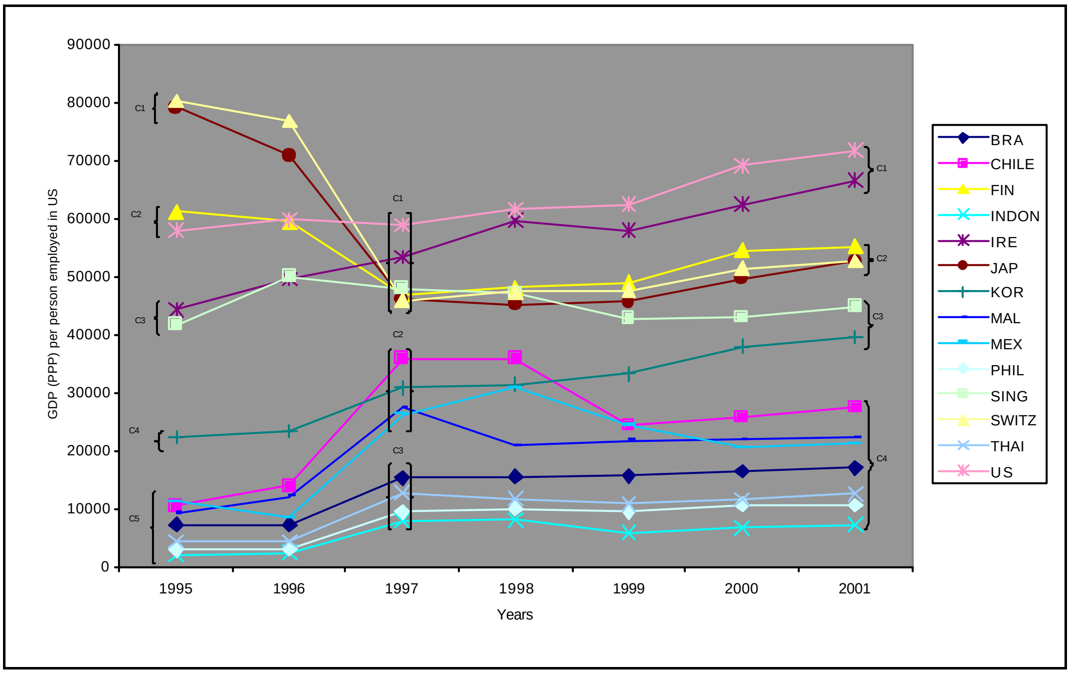
Countries in Cluster 3 in 1995 (expect for Singapore) saw an increase in service productivity level. By 2001, Finland, Japan and Switzerland formed Cluster 2 – grouping with the second highest service productivity level. South Korea, which was part of Cluster 4 in 1995, saw a significant increase in service productivity level of the sample period. The service productivity in South Korea and Singapore were closer in 2001, thus forming Cluster 3. Except for South Korea, there were no changes in cluster membership of Cluster 4 in 2001. Note that countries in this cluster have the lowest productivity level compared to countries in other clusters.

3.4.4 Overall Productivity

The trend for overall productivity is given in Figure 14. We observe formation of five clusters in 1995. Cluster 1 consisted of Switzerland and Japan, Cluster 2 consisted of Finland and the US, Cluster 3 consisted of Ireland and Singapore, Cluster 4 consisted of South Korea and Cluster 5 consisted of Mexico, Chile, Malaysia, the Philippines and Indonesia. By 1997, we observe emergence of three clusters. The overall productivity growth in the US and Ireland was on an increasing trend over the years. Ireland saw a sharp increase in overall productivity – moving up from Cluster 3 in 1995 to join the US in Cluster 1 in 2001.

Switzerland and Japan had the highest overall productivity in 1995. However by 1996, the overall productivity in these countries fell significantly. Similarly, Finland also saw significant fall in overall productivity level in 1996 before gradually experiencing an increasing trend after 1997. By 2001, overall productivity in Switzerland, Japan and Finland converged - forming Cluster 2. Singapore saw an increase in overall productivity from 1995 to 1998. However, the overall productivity in Singapore fell slightly in 1999. By 2001, Singapore diverged from Finland, Switzerland and Japan and formed Cluster 3, together with South Korea, which saw an increasing trend in overall productivity from 1996 onwards.

Figure 14: Trends in Overall Productivity



Developing countries saw an upward trend in overall productivity from 1995 to 1998. From 1999, the overall productivity's growth in these countries was small. Chile had the highest overall productivity growth over the sample period, followed closely by Malaysia and Brazil. Note that there was a significant gap between the developed and the developing countries in terms of the overall productivity from 1995 to 2001.

3.4.5 Summary

From the above empirical analysis, the US and Ireland seem to lead in all the productivity indicators, especially in the later years. This is followed by Finland, Switzerland and Japan. In the case of industrial productivity, Singapore and South Korea were close to Finland, Switzerland and Japan. In the other productivity indicators, Singapore and South Korea were below Finland, Switzerland and Japan, but significantly higher than other developing countries.

Developing countries had significantly lower productivity levels than the developed economies. Among the developing economies, the Latin American countries and Malaysia seem to be ahead of Indonesia, the Philippines and Thailand. Based on the empirical analysis, countries that have invested heavily in infrastructure, education and innovation, seem to have high level of labour - service - industry - and overall productivity. This finding is consistent with other empirical studies in the literature (e.g. Brynjolffson and Hitt, 1995 and Stiroh, 2001).

4. Competitive Strategies in the Information Economy: Lessons for Developing Countries

From the above empirical analysis, several important patterns have emerged over the years. First, developed countries such as the US, Finland, Ireland, Switzerland and Japan seem to invest heavily in infrastructure, human capital and innovation. In categories such as Internet users, software expenditure and R&D personnel, smaller developed countries, such as Ireland and Finland, seem to be ahead of the larger developed countries. Moreover, countries such as Singapore and South Korea seem to have converged closer to the developed countries in late 1990s.

Developing countries (Malaysia, Chile, Brazil, Thailand, the Philippines, Indonesia and Mexico) seem to lag behind developed countries in almost all the categories mentioned above. Among the developing countries, the Latin American countries (Brazil, Chile and Mexico) and Malaysia seem to be ahead of Indonesia, Thailand and the Philippines in ICT infrastructure, human capital and innovation factors.

We noted that countries investing heavily in infrastructure, human capital and innovation had high labor productivity, service productivity, industry productivity and overall productivity. In many of the developed countries, the growth in the above-mentioned factors and the productivity levels can be attributed to several policies implemented in these countries. First, in the developed countries, the level of competition in the telecommunication sector is higher. For example, Finland, a country with a population of 6 million, has 140 telecommunication operators. The telecommunication sector in Switzerland was liberalized in 1998. This led to growth of 340 operators in the country – this has intensified competition in the telecommunication sectors in this country (Salminen, 2003). Liberalization of the telecommunication and ICT sectors has also increased investment in the ICT infrastructure and infostructure in the developed countries. Competition in this sector has lowered cost of the services and increased ICT penetration rates.

In some developed countries, government interventionist policies have helped spur local technology to be globally competitive. For example, in Europe, the government adopted the GSM standard. This was done mainly to enhance service integration. This new technology is currently used globally. South Korea on the other hand enhanced the internationally recognized code division multiple access (CDMA) technology and applied them widely in their local mobile phone technology. This enabled them to become one of the world's leading CDMA based mobile phone operators (Dahlman and Andersson, 2000).

In many of the smaller developed economies, the government spearheaded the 'electronic revolution' - government led the way in providing high quality electronic services. Government also provided assistance and training for the small and medium enterprises to adapt to the new digital infrastructure. In all the developed countries, human capital development is given the highest priority in the development of national policies. Investment into the education sector (from primary to tertiary) has seen significant growth over the years.

For example, for a population of 6 million in Finland, there are 20 universities and 29 polytechnics. Further, ICT based education programs are integrated into all levels of education in Finland (Statistics Finland, 2001). Further in the developed countries, there were strong linkage between industry and universities. In many of the universities, industry forms a part of consultative group that provides recommendation for curriculum development. Thus, with increased investment in human capital (especially in ICT), and strong linkages with industry, the levels of labor productivity in these countries are also high.

Another important factor that has enhanced the competitiveness of developed countries is the high investment in innovation. In many of the developed countries such as the US, Finland, Ireland and Switzerland, much of the R&D investment are done by the private sector. This includes funding for basic research and training R&D personnel. Besides the increase in R&D funding, government, private sector and universities closely manage innovation. Government play a key role in providing effective institutions, regulatory framework and conducive macroeconomic environment for homegrown technologies to compete globally. The private sector works closely with universities to collaborate on new initiatives and innovations. The universities not only contribute to the development of new technology and 'know-how', but also become incubators for training research personnel for the industry.

In many of the developed countries, this Tri-partite partnership (between government, universities and the private sector) has also seen the emergence of 'Centers of Excellence' that spearhead research initiatives that are strategic to the nations' competitiveness. For example, NeuroScience Center (public enterprise) and Novartis (private firm) from Switzerland agreed to undertake joint research work in the medical area. This resulted in establishment of 90 research centers around the globe, employing 220 neuroscientists (Vock, 2000). In Finland, almost two thirds of the R&D investment is in the electronics sector. A significant portion of the R&D funding is undertaken by Nokia, which has 52 research centers in 14 countries (Salminen, 2003). These global strategic partnerships in innovation have several benefits. First, it allows local firms to be in tune with cutting edge R&D activities globally. Second, it provides firms' access to personnel and resources that are cheaper from other parts of the globe. Third, it allows the firms to have access to larger market share for their goods and services (which includes R&D services).

4.1 Summary

In summary, we have identified five policy initiatives that require attention in the national development policies of developing countries. First, developing countries need to provide a conducive socio-economic environment as a platform for inflow of foreign participation in the domestic economy. In other words, developing countries need to have a stable political environment and appropriate and dynamic economic policies. Second, developing countries need to continuously create basic and advanced infrastructure to support ICT diffusion in the economy. This refers to availability of cheap and reliable computers as well as high-speed access to Internet – broadband.

One possible way of achieving this would be to liberalize the telecommunication sector in the economy. This would enable creation of a competitive and innovative environment, thus, enhancing economic growth. Third, developing countries need to focus on developing the skills and knowledge of the human capital in tandem with dynamic evolution of the information economy. This refers to advancement in ICT based education and continuous upgrading of the syllabus to meet the need of the industry and economy as a whole. Effective use of the ICT infrastructure and technologies will depend on the absorbability of the human capital in the country. Fourth, developing countries need to focus on inculcating innovation at the micro (worker) and macro level (industry). This is associated with the education and research training policies that are able to kindle the innovative mind in the worker and spurs innovation in the firms, industries and the economy.

In many developed economies, various incentives and facilities are provided to workers and researchers to innovate and patent their breakthroughs. In many of these countries, patent offices assist researchers to patent their finding for a nominal fee. Another important institution that can be a source of dissemination of information on the R&D activities in the country is an Intellectual Property Bank (IP Bank). Besides registering patents, IP Banks also can be a one-stop center for finding out patented R&D that have been commercialized and not commercialized. This will open up a new market for commercialization of patents - firms may be able to help researchers to commercialize their patents for a fee.

Lastly, there should be greater linkages between government, industry and universities in enhancing the quality of the infrastructure, human capital and innovation in the country. The pooling of resources by government, industry and universities will have a multiplier effect in enhancing the competitiveness of the resources in the countries - thus, increasing their labour, industrial, service and overall productivity.

5. CONCLUSIONS AND FUTURE RESEARCH

In this paper, we examined the trends for several important factors that are relevant to the information economy, namely, infrastructure, human capital and innovation, for selected developed and developing countries. We also examined the trends of four types of productivity indicators (labor, service, industry and overall productivity). The result from this study showed that developed economies such as the US, Finland, Ireland and Japan have consistently increased investment in infrastructure, human capital and innovation over the sample period.

The empirical evidence also suggests that these countries have high productivity levels (labor, service, industry and overall). Countries such as Singapore and South Korea seem to be converging closer to the developed economies. On the other hand, the gap in infrastructure, human capital and innovation have been widening between the developing countries (Malaysia, Chile, Mexico, Brazil, Thailand, the Philippines and Indonesia) and the developed countries. Similar trends emerge for the four productivity indicators.

In this paper, we also examined some of the policies and strategies employed by the more developed economies to maintain their competitive position in the new economy. These findings will be important in the formulation of better policies pertaining to infrastructure, human capital and innovation in developing countries. Future research work should employ a larger number of countries and factors for the information economy. In order to have a better understanding of the trends in the factors and the productivity indicators, future research should use a systematic multivariate approach to uncover the clusters in the sample. This will lead to more accurate understanding of the convergence and divergence phenomenon in the information economy. Thus, leading to more accurate formulation of policies and strategies that will facilitate developing countries to 'catch-up' with the more evolved economies.

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