WHOSE ICT INVESTMENT MATTERS TO ECONOMIC GROWTH: PRIVATE OR PUBLIC? THE MALAYSIAN PERSPECTIVE

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ABSTRACT
Theoretical and empirical research on the economic benefits of ICT is represented in academic and policy-related publications worldwide. Most of these studies assess the impact of ICT in countries as a cohort and most conclude that ICT is indeed a key driver for economic growth. Nevertheless, we are of the opinion that there is room for more research on this issue, especially pertaining to developing countries such as Malaysia, in light of the extensive ICT-based investments undertaken by the country in recent years. Consequently, we examined the effect of ICT investment carried out by both the private and public sector on Malaysia's economic growth over the period 1992 – 2006 using the ARDL econometrics approach. The empirical results suggest that ICT has had a significant impact on Malaysia's economic growth during this period of time, suggesting good payoffs from the investment. Specifically, ICT investments made by the private sector seem to have contributed significantly to the country's growth compared to investments made by the government. This implies that the private sector has adapted well to the various ICT-based policies implemented in the country over the years. This also shows that Malaysia's economy is being driven by the private sector, especially by the manufacturing and wholesale industries. We are however of the opinion that in order to sustain economic growth leveraged against ICT, more concerted efforts need to be made in order to escalate ICT diffusion in the country. Such initiatives will ensure that the value potential of ICT investments in the economy is maximized, due to greater ICT-enabled community that will translate to escalated economic growth.
Keywords: *ICT, Malaysia, economic growth, public-private sectors*

1. INTRODUCTION

The world is currently in a state of social, economic and environmental change. Issues such as globalization, heightened terrorism activities post 9/11, and tsunamis/hurricanes have had powerful impact on national economies, especially in developing nations. Past economic growth models (modeled mainly by developed countries), are said to be irrelevant to developing nations (John et al., 2006) – chiefly due to the emergence of the 'ICT led economic growth model'. This model does not replace the past growth models, but rather supplements it, which means that ICT led growth supports the provisions catered by the conventional models such as the provision of basic priorities to people (i.e. food, shelter and health), good governance, political stability and stable social development. The support comes from the way these basic models are implemented in countries, that is the driving conditions that amplifies the nurturing of economic growth in developing countries.

For a developing country such as Malaysia, competing in the global market has become more challenging and complex. Attaining competitiveness is not only about liberalization of the economy, but also entails how far ICT is being used in the country. Since ICT benefits all activities (for example the shrinking of economic space due to communication advancement has enabled reduction in transaction and information costs), wider diffusion is vital to ensure national welfare. To this end, governments of developing countries are pressured to increase ICT diffusion in the economy to maximize the benefit from technological investments. In essence, strategic policies have to be catered to address failures in achieving global competitiveness rather than building production capabilities in relative isolation (UN, 2003). This means that the important ingredients (i.e. all resources available in the country) need to be 'plugged' into the global market in order to maximize the payoffs from ICT investment. As highlighted by UNCTAD (2003, p.5) "the need for strategy remains, but the kind of strategy that will maximize ICT diffusion is new".

In Malaysia, ICT has entered people's lives in many ways – be it in terms of communication, logistics or in their working environment. The country has invested enormously in ICT over the years. For instance, in the newly launched five-year country growth plan (called the Ninth Malaysian Plan, 2006-2010), a total of US$6 billion was allocated for enhancing ICT diffusion throughout the country. This shows the importance given by the country for ICT to accelerate the economic competitiveness of Malaysia. Apart from the public sector, the private sector in Malaysia is a major user of ICT products and services. This sector has also invested significantly in ICT over time. The key question is whether the investment made by both public and private sectors has benefited the country in terms of economic growth. This paper aims to address this issue by empirically examining the impact of ICT investment made by the public and private sectors in Malaysia on its economic growth over the period 1992 to 2006. The rest of the paper is organized as follows. Section 2 provides an overview of the impact of ICT on economic growth. Section 3 highlights the ICT revolution in Malaysia. This is followed by a discussion of the methodology and results in Section 4 and 5 respectively. Finally, Section 6 presents the conclusion and policy recommendations.

2. THE IMPACT OF ICT ON ECONOMIC GROWTH: A REVIEW

In the last three decades, numerous studies have been undertaken to examine the impact of ICT on a country's economic performance, fuelled largely by Robert Solow's (1957) seminal work. In the paper, Solow argued that the United States (US) economic growth during 1950s and 1960s was attributed mainly to 'technological change' as opposed to the conventional factors of labour and capital. Since then, various firm, industry and country level studies have been undertaken on this issue, primarily for developed countries, whilst developing countries have been studied more recently. In this section, we will review some of the key studies that have examined the impact of ICT on economic growth both in developed and developing countries. Studies for developed economies have commonly employed the Cobb-Douglas production function to estimate the contribution of the ICT investment to economic growth. The conclusions drawn from these studies are mixed – some found positive impact while others found negative relationship.

In the context of negative findings, Berndt et al. (1992) examined the contribution of ICT capital to US industries' productivity growth and found a negative relationship. Parsons et al. (1990) argued that Canadian banks did not reap good benefits from their ICT capital investments. Similar findings were reported by Morrison (1997) whom reported insignificant relationship between ICT and economic growth of the US firms.

Some of the studies had found positive and significant relationship between ICT and economic growth. In early 1990s, Lau and Tokutsu (1992) investigated the contribution of ICT investment on economic growth in the US for the period 1960 to 1990. The empirical result showed that nearly half of the growth in the aggregate national output in the US was attributed to ICT investment than non-ICT capital or labour. Schreyer (2000) estimated the impact of ICT on labor productivity amongst G7 nations. He found that the employed sample countries (i.e. Germany, Canada, Italy, Japan, US and UK) had benefited significantly from ICT investment in terms of remarkable average annual labour productivity growth over the period 1990 to 1996. Daveri (2000) updated Schreyer's (2000) research work and extended it to another eleven OECD countries. Apart from using similar data, Daveri also added software to ICT capital. Here, the author found similar results - ICT contributed substantially to economic growth during the later part of 1990s for all the sample countries (though the magnitudes differ greatly across the countries).

Poh (2001) investigated the impact of ICT investment on overall productivity in Singapore over the period 1977 to 1997. The estimated result showed that ICT capital generated significant rate of return to the economy. Two years later, Kim (2003) examined the impact of ICT on productivity and economic growth in Korea during 1971 to 2000 sample period. The results showed that ICT capital contributed 16.3% to the output growth and has had strong positive effect on the growth of labor productivity in the long run.

Several studies have examined the contribution of ICT to economic development of developing countries in recent years. To quote a few, Kuppusamy and Solucis (2005) and Kuppusamy and Shanmugam (2007) examined the impact of ICT to Malaysia over the periods 1975 – 2002 and 1983 – 2004, respectively. It was found that ICT investment has statistically improved Malaysia's economic growth in both studies.

In sum, the issue of ICT and economic growth has received much attention with respect to the developed countries as opposed to the developing countries. John et al. (2006, p.51), highlighted that ICT enhances economic growth of developing countries by way of:

- Providing cheaper, quality, and empowered communication to marginalized communities
- Reduce inequalities in terms of access to education, training and employment
- Provision of easier access to information and wider market reach to firms (by way of cost reduction)
- Reduction in government bureaucracy via the electronic government service system
- Fostering closer collaboration and interaction between various stakeholders in a country.

Note that the benefits of ICT are not limited to the above-mentioned only. There are other benefits as well. However we highlighted only selected benefits of ICT to a country in this section of the paper.

In a series of empirical research studies, Nair and Kuppusamy (2004) and Nair et al., (2005a, 2005b) highlighted the existence of ICT diffusion disparity between developed and developing countries. The key question now is what have the developed countries done to widen ICT diffusion in their country, that the developing countries are not doing? In the case of Malaysia, significant investments have been made to integrate ICT into all sectors of the economy. So has the country benefited from such investments (via economic growth in this context), or it is just a waste of good money? We answer these research question via the empirical findings from this paper. But first we briefly review Malaysia's efforts to embrace the ICT revolution.

3. ICT Revolution in Malaysia

In order to catch up with more evolved economies, Malaysia undertook several bold initiatives over the last thirty years, mainly to enhance ICT diffusion in the country. The initiatives can be categorized into macro and micro level initiatives. The macro level initiative is focused at the development of the Multimedia Super Corridor (MSC) – the heart/umbrella of ICT development in Malaysia, while the micro-level efforts are focused at provision of advanced ICT-enabling infrastructure, establishment of dynamic institutions that supports ICT growth in the country, creation of vibrant and skilled human capital, and increasing innovation activities in the country. Some of the key initiatives are discussed in this section.

3.1 Macro Level ICT Initiatives – the Multimedia Super Corridor (MSC)

The MSC was established in 1996. It is a key platform that helps to build a competitive cluster of local ICT companies and a sustainable ICT industry (Government of Malaysia, 2001). The MSC is considered a long-term strategic initiative (1996-2020) which involves a partnership between the Government (as the chief architect of its vision) and the private sector (as the main drivers for its implementation). Basically, the MSC is a dedicated corridor (15 kilometers wide and 50 kilometers long) which stretches from the Kuala Lumpur City Center in the north to the new Kuala Lumpur International Airport (KLIA) in the south. Besides offering ICT initiatives, the corridor attracts global ICT companies for relocation of their multimedia industries in Malaysia, to undertake innovative research & development, while developing new products and technologies and export from this corridor as their base. In other words, MSC becomes a base for local entrepreneurs to transform themselves into world-class companies.

Initially, the response to MSC was poor with less than 200 companies relocating to MSC region. However, by the end of 2005, a total of 1,421 companies were awarded MSC status (9MP, 2006-2010), which is expected to increase to 4,000 companies by the year 2010. This will help to create more job opportunities for Malaysians nationwide. Apart from that, MSC will also help to increase adoption of locally developed ICT products and services. Under the Ninth Malaysia Plan, the MSC is expected to be rolled out to other cities like Bayan Lepas in Penang, Johor Bahru in Johor, Kulim Hi-Tech Park in Kedah, Sabah and Sarawak. This is expected to result in an additional 250 global corporations joining the project.

3.2 Micro Level Initiatives -- ICT Infrastructure

For the past thirty years, Malaysia concentrated on building the right infrastructure to support ICT growth in the country. Establishment of proper infrastructure ensures speedy and efficient network of facilities and services for better diffusion of ICT. During the 1980s, most of the ICT infrastructure investment went into provision of basic telephony services to rural and urban people. During the 1980s, concerted efforts were given to increase access to mobile and fixed-line services to wider segment of the population. One of the key initiatives during this period was the privatization of the state-owned telecommunication provider, Telekom Malaysia, which helped in improving market reach of telecommunication services.

During the new millennium, Malaysia focused on increasing accessibility to Internet and its related services. To this end, investments on wired and wireless technologies were made to increase broadband services throughout the country. Apart from that the government catered for competition in the telecommunication services by allowing entry of new players such as Digi, Maxis and Celcom. This resulted in creation of innovative and competitive products and services in the country (especially cheaper Internet service). Further, ICT connectivity in rural areas was intensified between 2000 and 2003. In 2000, 33 pilot community-based Internet Centres were developed nationwide (12 of which were in rural areas); with an additional 31 Internet / Information Centres established across the nation between 2001-03 (Economic Planning Unit reports, 2001 & 2003); and an NITC Strategic Task Force, experimented with a Public-Private Partnership model for another 13 pilot projects nationally (John et al., 2004).

All the above-discussed initiatives were undertaken during the Eighth Malaysian Plan (2001-2005). The efforts to digitize the country were continued under the Ninth Malaysia Plan (2006-2010), where a total of RM12.9 billion was allocated for ICT related programs and projects (refer to Table 1). A major portion of this allocation was for establishment of advanced electronic government services, as well as further enhancement of Internet penetration in the country.

Table 1: Development Expenditure and Allocation for ICT related programs, 2001-2010

Programs	**8MP (RM million) Expenditure**	**9MP (RM million) Allocation**
Computerization of Government Agencies	2 125.0	5 734.2
Bridging the Digital Divide:	2 433.1	3 710.2
➢ School	*2 145.1*	*3 279.2*
➢ Communications Infrastructure Service Provision Programs	*254.0*	*150.0*
➢ Telecentres	*18.1*	*101.1*
➢ ICT Training/Services	*15.9*	*180.0*
ICT Funding	1 125.6	1 493.0
MSC Multimedia Applications:	1 153.1	1 100.5
➢ e-Government	*537.7*	*572.7*
➢ Smart School	*363.9*	*169.8*
➢ Telehealth	*91.8*	*60.0*
➢ Government Multipurpose Card	*159.7*	*298.0*
MSC Development	320.8	377.0
Research and Development	727.5	474.0
Total	**7 885.1**	**12 888.9**

Source: Economic Planning Unit (2006)

As a result of the above mentioned and other initiatives, there was a significant increase of fixed phone line, mobile phone subscription and Internet penetration in the country over the years. Table 2 shows the growth of the three ICT related services for the year 2000, 2005 and 2010 (estimated). It can be seen that fixed phone line per 1000 people was 19.7% in 2000, but fell slightly to 16.6% in 2005, possibly due to increased mobile phone service usage. This is because mobile phone penetration increased from 21.8% in 2000 to 74.1% in 2005, which is expected to increase to 85% per 1000 people by 2010. In terms of Internet access, in 2000 a total of 7.1% of every 1000 people had Internet access. This increased significantly in a span of five years to 13.9% in 2005, and is expected to increase to 35% per 1000 people in 2010.

Table 2: Selected ICT Investment Indicators, 2000-2010

Indicator	**2000**	**2005**	**2010e**
Fixed Telephone Lines in Operation			
➢ Number of Lines (million)	4.6	4.4	-
➢ Penetration Rate % (per 1000 population)	19.7	16.6	-
Mobile Phone Subscriptions			
➢ Number of Subscriptions (million)	5.0	19.5	24.4
➢ Penetration Rate % (per 1000 population)	21.8	74.1	85.0
Personal Computers Installed			
➢ Number of Units Installed (million)	2.2	5.7	11.5
➢ Penetration Rate % (per 1000 population)	9.4	21.8	40.0
Internet Dial-up Subscriptions			
➢ Number of Subscriptions (million)	1.7	3.7	10.0
➢ Penetration Rate % (per 1000 population)	7.1	13.9	35.0
Internet Broadband Subscriptions			
➢ Number of Subscriptions (million)	-	490, 630	3 733 000
➢ Penetration Rate % (per 1000 population)	-	1.9	13.0

Source: Malaysian Communications and Multimedia Commission (MCMC) & Economic Planning Unit (EPU) data as at October 2005.

3.3 Micro Level Initiatives -- ICT Governance

Embracing the digital revolution requires good ICT governance. As highlighted by Nair et al., (2005), for ICT to contribute to economic growth, a conducive legislative environment should be in place to support communication, commerce and trade in the digital medium. To this end, Malaysia has established several regulations that govern ICT related products and services in the country. For example, the Digital Signature Act was established in 1997, and facilitates electronic commerce and online transactions via the usage of digital signatures. In the same year, the Computer Crime Act (1997) was created. This Act provides for offences relating to the misuse of computers; it aims to clearly define activities such as cyber fraud, unauthorized access, interception and illegal use of computers. The Communications and Multimedia Act (1998) was developed to cater for the convergence of the telecommunications, broadcasting and computing industries in Malaysia. The Data Protection Act (2002) governs issues pertaining to privacy, authentication and protection of personal and business information that are used in formal business and social transactions.

3.4 Micro Level Initiatives – Human Capital

Embracing ICT revolution is not only about having the right infrastructure and regulation, but also about having the right people. Human capital is a key component of the digital economy. Here, having ICT savvy workforce ensures absorption of new knowledge and skills that can be used to generate productive output. In this context, the Malaysian government has undertaken various action-plans to cater the rising demand for skilled ICT savvy human capital in the country.

One of the primary initiatives to this end is the incessant increase in education investment in the country. In 1980, the government's education investment was 7.5% of total GDP. This increased to 17% of GDP in 2003. The number of universities, university colleges, polytechnics and colleges were also increased over the last decade. There are 11 public universities, 10 private universities (4 run by Government-led private sector), 7 public university colleges, 10 private university colleges, 20 polytechnics, 34 community colleges and 282 other private institutions of higher learning. The tertiary education sector was opened, with 4 foreign universities having established campuses (i.e. Monash University, University of Nottingham, Curtin University and Swinburne University of Technology) in Malaysia (John et al., 2006).

Malaysia introduced ICT based learning environment in schools since late 1990s. In 1999 12,000 schools were equipped with PCs and Internet (EPU, 2003) and by end-2005 all 18,000 schools will have ICT-enabled learning. Rural schools were linked to the Internet using the Very Small Aperture Terminal (VSAT) and wireless loop technology. The MySchoolNet portal was established to enable teachers and students to source educational material and information. The opening of the Multimedia University in 1996 was another milestone for the Malaysian education sector – as this university is specialized in generating ICT manpower for the country (EPU, 2003). Greater emphasis was also given to Science and Technology (S&T) education at the tertiary level under the 8th Malaysia Plan (2000-05) with 60% of graduates in 2005 expected to be in S&T area (EPU, 2001).

To date, a total of 31,000 ICT graduates were produced by the 48 MSC status local education institutions (Ninth Malaysian Plan, 2006-2010). Table 3 shows the number of ICT workers in Malaysia for the period 2000-2002. The ICT sector is divided into five categories – hardware consultancy services, software consultancy & supply, data processing services, database activities and maintenance and repair of computers. It can be seen that in 2000, hardware consultancy and software consultancy & supply workers totaled 2.68 million and 7.64 million respectively. This reduced slightly to 1.62 million workers in 2001 for hardware consultancy, and increased to 10.2 million workers for software consultancy & supply. By 2002, the ICT related employees in hardware consultancy reduced further to 1.47 million workers.

Meanwhile ICT workers in software consultancy increased to 13.8 million workers. Growth trends can be seen for data processing services and maintenance and repair of computers category. However, there is a marginal reduction in database activities category – the growth in the number of workers was hampered from 472 thousand workers in 2000 to 253 thousand in 2001. However, the number of workers increased again in 2002 to 683 thousand for this category of ICT sector.

Further, funding for S&T based education was increased. Enrolments in S&T undergraduate program is envisaged to increase to the ratio of 60 (science): 40 (arts). Apart from the above initiatives, Malaysia also took measures to reverse the 'brain-drain' problem. Local professionals who were residing in foreign countries were encouraged to return to work in key sectors of the economy in Malaysia. Further, local universities were allowed to employ foreign experts, if suitable local experts could not be found. By the end of 2000, a total of 23 Malaysian and 70 foreign scientists were brought into the country.

Table 3: The ICT related workers in Malaysia 2000, 2001 & 2002 (in millions)

Number of ICT workers	**2000**	**2001**	**2002**
Hardware consultancy services	2,689.00	1,616.00	1,471.00
Software consultancy and supply	7,642.00	10,220.00	13,799.00
Data processing services	809.00	831.00	2,645.00
Database activities	472.00	253.00	683.00
Maintenance and repair of computers	628.00	621.00	1,430.00

Source: Economic Census 20003, Statistics Department Malaysia

One of the latest initiatives to increase ICT skilled human capital was the setting up of the Human Resource Development Fund (HRDF). The HRDF is responsible to provide training funding to corporations which sends their staffs for skill enhancement programs throughout Malaysia. During the 2001-2005 period, a total of RM176 million was spent for this purpose, which involved financing of 241,359 training programs nationwide.

3.5 Micro Level Initiatives – Enhancing Innovation

Malaysia's innovation related policies are centered on achieving the following objectives (Eighth Malaysian Plan, 2000-2005):

a. Promoting technological innovation and escalating the number of skilled and research based workers in the country.
b. Commercializing public sector's innovation capital.
c. Improving efficiency and effectiveness of local research agencies, which play a key role in technology transfer, and to close the divide between research institutions, academic sector and industries.
d. Intensifying knowledge and information dissemination culture in order to build strong innovation capabilities in the country
e. Increasing the competitive strength of indigenous industries by building new enabling technologies.
f. Intensifying inter-governmental cooperation in the field of innovation. This will help in better coordination between innovation policies and the country's economic development policies.
g. Establishing stronger linkages with international sources in order to gain better access to advanced technologies.
h. Developing a measurement and monitoring system to ensure effectiveness of innovation performance in the country.

Malaysia's innovation development can be categorized into research and development (R&D) activities (both by government and private sector), technology transfer initiatives, innovation based manpower, commercialization of R&D projects, and the thrust towards building an innovation based society.

3.5.1 Public Sector R&D

Since the 1960s, the public sector in Malaysia has contributed significantly to the expansion of the innovation process in the country, made largely through investment into agriculture-based R&D activities. In the early 1990s, the public sector shifted its R&D focus - from agriculture based, to ICT services. Under the 7th Malaysian Plan, a total of RM935 million was allocated for R&D programs in Malaysia. From this, RM755 million was allocated for public sector involvement in Intensification of Research in Priority Areas (IRPA) research activities. Over the period 1996 to 2000, the government approved a total of 3,705 IRPA projects, with a disbursement of RM698 million. Agriculture-based research funding accounted to nearly 26% or RM178 million, followed by the Science and Engineering research area (16.4% or RM114.5 million) and Medical research area of 13.9% or RM96.99 million (Eighth Malaysian Plan, 2000-2005, p.342).

Apart from that, Malaysia allocated RM35 million for a collaborative program with the Massachusetts Institute of Technology (MIT) in 1999. This program concentrated on building the country's biotechnology industry, namely in the areas of plant, animal, medical, industrial/environmental, food, biopharmacy and molecular biology. Malaysia allocated the balance of RM145 million for three major research programs - the Industrial Research and Development Grant Scheme (IGS), MSC Research and Development Grant Scheme (MGS) and the Demonstrator Applications Grant Scheme (DAGS). IGS program, which was established in 1997, concentrated in fostering cooperation among private sectors, universities and research institutes in undertaking joint research projects. By 2000, a total of 56 projects were approved under this scheme (valued at RM138 million).

In early 1998, the MGS program was initiated to provide matching fund for research programs undertaken by local companies. By end of 2000, a total of 19 projects (valued at RM38 million) received approval under the MGS program. In April 1998, Malaysia established the DAGS program for the purpose of promoting diffusion of ICT in the country. This program enables Malaysians to develop custom-based software for specific community needs. By end of 2000, a total of 37 projects received a total of RM48 million under this program. Under the 8th Malaysian Plan, the public sector is anticipated to continue with its R&D programs with an allocation of RM6.1 billion. The IRPA funding system was fine-tuned to provide greater emphasize on the commercialization of relevant R&D projects. To this end, 32% of IRPA funding was allocated for research works in the area of manufacturing, plant production, ICT, health and education. An additional 35% were gazetted for R&D activities in the area of optical technology, chemical technology, software design technology, nanotechnology and precision engineering. Under the 8th Malaysian Plan, both government research agencies and the local universities are expected to play bigger roles in building the basic research capacity in the country. A total of RM100 million has been allocated for universities to conduct basic research.

3.5.2 Private Sector R&D

The private sector has continuously played a major role in Malaysia's economic growth. The growth in the private sector depended largely on its innovative capabilities in providing market driven products. To this end, the private sector has invested significantly into R&D activities over the years. For example, the private sector's R&D expenditure accounted to RM400 million in 1996, and this was increased to RM746 million in 1998. By 2000, the private sector's R&D expenditure increased to RM969 million. The R&D activities undertaken by the private sector in the country were mostly applied research (almost 90% of the total R&D expenditure). The remaining 10% accounted for basic research.

In terms of economic sectors, the manufacturing, ICT services, plant production and primary products were the main R&D-driven sectors in Malaysia. The private sector mainly concentrated on developing electronics equipment and components, transport equipment and petroleum based products. Generally, local companies undertake wide ranging industrial R&D. However, foreign companies based in Malaysia normally concentrate on high technology and high precision based R&D. One of the main reasons for the increase in R&D activities in the private sector is the attractive financial incentive scheme provided by the government. Among the major schemes introduced by the government are the double deduction R&D expenditure scheme, pioneer status for R&D companies and investment tax allowances (ITA) of up to 100%.

In 1995, 247 projects qualified for the double deduction R&D expenditure scheme, totaling to RM42 million. This increased to 387 projects or RM51 million in 1998. In 1999, a total of 531 projects obtained double deduction R&D expenditure of RM279 million. In other development, a total of 50 companies (largely from the electronics and transport equipment industries) obtained the pioneer status (ITA) for undertaking in-house R&D activities over the period 1996 to 2000. Total capital expenditure of these companies amounted to RM844 million during this period.

3.5.3 Technology Transfer

Over the years, Malaysia has taken steps to encourage technology transfer in all major economic sectors. For instance, Malaysia eased technology transfer approval process by creating an automatic approval system with a royalty payment of 3% or less of net annual sales. Such move has intensified technology transfer in the country. For example, the electrical and electronics industry recorded the highest number of technology transfer agreements over the years. In 1995, this industry recorded a total of 32 technology transfer agreements. By 1998, the total technology transfers agreement in the electrical and electronic industry increased to 50.

In the 8th Malaysian Plan, Malaysia continued to focus on acquiring new technologies from foreign countries. For this purpose, the government established a venture capital fund that will be used to invest in foreign companies. A total of RM500 million was allocated under the ICT Fund in 2000 to finance high technology based projects. In 2000, a total of RM27.3 million was approved under this fund. Further, a technology transfer program that oversees placement of Malaysian personnel in the acquired technological companies will also be created. This program assists the personnel to involve directly into the conceptualization, development and relocation of foreign manufacturing plant and R&D facilities in Malaysia. To this end, MIMOS Berhad continues to play its role to monitor the participation of local firms in foreign ventures that specializes in technologies related to ICT and life sciences. Under the 8th Malaysian Plan, an additional RM250 million was allocated under the Technology Acquisition Fund (TAF) program. This fund will be used to purchase high-technology equipment and machinery, as well as for patenting process in the country.

3.5.4 Commercialization of R&D

The public sector has played an important role in enhancing R&D activities in Malaysia. However, there was little effort made to commercialize the research outputs in Malaysia prior to mid 1990s. In a survey conducted by the government during the 6th and 7th Malaysian Plan, it was found that from a total of 5,232 R&D projects conducted in local research institutions and universities, only 5% were actually commercialized. Thus, in 1997, the Commercialization of Research and Development Fund (CRDF) was established with a total allocation of RM100 million. The specific focus of the fund is to commercialize research findings by local universities, research centers, companies and individual researchers. By the end of 2000, close to 40 projects (with a value of RM32 million) were granted funding and 12 projects have been commercialized. Further, the IGS, MGS and DAGS grant schemes has been strengthened to support commercialization of R&D projects. A total of RM610 million have been allocated under the 8th Malaysian Plan for this purpose.

3.6 Summary

Over the past decade, Malaysia has undertaken significant efforts to enhance ICT developments in the country, with the private sector taking active role as well. These initiatives were carried out within the framework of ICT-led economic growth model. In the next section, we will examine if the above mentioned initiatives are producing the required tangible outcomes for Malaysia.

4. METHODOLOGY

This study examines the effect of ICT investments on Malaysia's economic growth using a robust cointegration and error correction method called as the Bounds Test (Pesaran et al., 2001) and Unrestricted Error Correction Method (UECM) (Banerjee et al. 1998). Most past studies have not given much concentration on the cointegration issue. This may be because conventional cointegration method, such as Engle and Granger (1987) and Johansen and Juselius (1990) require large number of sample size. In addition, the order of the integration needs to be either *I*(0) or *I*(1). However, this is not a necessary pre-requirement for the case for the UECM approach. In this method, the order of integration can be either stationary (*I* (0)) or non-stationary (*I* (1)). Moreover, the Bounds Test can be employed in a small sample study such as the present study. Note that there is no specific definition as to what constitutes small or large sample size, but the general practice is that large sample size constitutes studies that uses a sample of at least 50 years.

4.1 The Data and Sample Period

The data for this study was gathered from the World Information Technology Service Alliances (WITSA) annual report on worldwide growth of Information and Communication Technology (ICT). The variables used in the study are measured in US dollars. We used data on ICT investment by three major private sectors in Malaysia, namely agriculture, manufacturing, and wholesale as well as ICT investment made by the government. These variables form the independent factors, while data on real gross domestic product (real GDP) becomes the dependent factor. The sample period used in this study is from 1995 to 2006. The empirical model based on the employed data is as follows:

$$RGDP_t = \beta_0 + \beta_1 \, ICTag_t + \beta_2 \, ICTman_t + \beta_3 \, ICTwho_t + \beta_3 \, ICTgov_t + e_t \qquad (1)$$

where,

RGDP	=	real gross domestic product (US dollars)
ICTag	=	ICT investment by the agriculture sector
ICTman	=	ICT investment by the manufacturing sector
ICTwho	=	ICT investment by the wholesale sector
ICTgov	=	ICT investment by the Malaysian government
ε	=	error term

4.2 The ARDL Framework

In this study we have employed the autoregressive distributed lag (ARDL) framework developed by Pesaran and Shin (1995, 1999), Pesaran et al. (1996) and Pesaran (1997) to model the impact of ICT investment on Malaysia's economic growth over the period 1995 to 2006. This framework has several advantages compared to the conventional cointegration methods such as Johansen (1998) and Johansen and Juselius (1990). The conventional approaches estimate long run relationships between a dependent and its regressors within the context of equations system. The ARDL however employs only a single reduced form equation (Pesaran and Shin, 1995). The ARDL can be employed regardless of whether the underlying regressors are purely *I* (0) or *I* (1), or mutually cointegrated. ARDL also avoids the larger number of specification to be made in the standard cointegration test, which include decisions regarding the number of endogenous and exogenous variables to be included, the treatment of deterministic elements, and the optimal lags to be specified (Duasa, 2007). This means that the ARDL framework allows different variables to have different optimal lags which are rather unfeasible with the conventional cointegration approaches. Last but not the least, ARDL works well with small sample studies such as the present one, which means that cointegration can be undertaken for 30 to 80 observations.

Basically, the error correction (EC) representation of the ARDL cointegration for Malaysia's economic growth and ICT investment by the three economic sectors is as follows:

$$\Delta RGDP_t = \alpha_{0ICT} + \sum_{i=1}^{p} \beta_{iICT} \Delta RGDP_{t-i} + \sum_{j=1}^{q} \delta_{iICT} \Delta ICTman_{t-i} + \sum_{k=0}^{r} \omega_{iICT} \Delta ICTag_{t-i} + \sum_{l=1}^{s} \chi_{iICT} \Delta ICTwho_{t-i}$$
$$+ \sum_{k=0}^{r} \partial_{iICT} \Delta ICTgov_{t-i} + \lambda_{2ICT} ICTman_{t-1} + \lambda_{3ICT} ICTag_{t-1} + \lambda_{4ICT} ICTwho_{t-1} + \lambda_{5ICT} ICTgov_{t-1} + \varepsilon_{1t}$$

In order to test the existence of a long run relationship between the dependent and independent variables, the *F-test* is used. Should there be a long run relationship; the *F-test* will indicate which variable should be normalized. The null hypothesis of no cointegration amongst the variables is as follows:

H_0: $\lambda_{1RDGP} = \lambda_{2RGDP} = \lambda_{3RGDP} = \lambda_{4RGDP} = \lambda_{5RGDP} = 0$
H1: $\lambda_{1RGDP} \neq \lambda_{2RGDP} \neq \lambda_{3RGDP} \neq \lambda_{4RGDP} \neq \lambda_{5RGDP} \neq 0$

The *F-test* has a non-standard distribution that depends upon two major factors. First, the distribution depends on whether the variables included in the ARDL model are *I* (0) or *I* (1). Second, the non-standard distribution also depends on the number of regressors and whether the ARDL model contains an intercept and/or a trend. Two sets of critical values (CVs) were reported by Pesaran and Pesaran (1997) and Pesaran *et al.* (2001). Since these two sets of critical values provide critical values bounds for all classification of the regressors into purely *I* (1), purely *I* (0) or mutually cointegrated- the ARDL approach is also referred to as a bounds testing procedure (Pesaran et al.*,* 2001). If the computed *F* statistics falls outside the critical bounds, a conclusive decision can be made regarding cointegration without the need for knowing the order of integration of the regressors. For instance, if the empirical analysis shows that the estimated *Fs* (.) is higher than the upper bound of the CV then the null hypothesis of no cointegration is rejected. In case that the computed *F* statistics falls inside the upper and lower bounds, a conclusive inference cannot be made without further tests.

The orders of the lags in the ARDL model can be selected by either the Akaike Information criterion (AIC) or the Schwartz Bayesian criterion (SBC), before the selected model is estimated by ordinary least squares. For annual dataset, Pesaran and Shin (1999) recommended choosing a maximum of 2 lags. From this, the lag length that minimizes SBC is selected. Optimal lag length selection approach shows that if one model stands out among the others in term of the goodness of fit or the parsimonious specification, it must be the best-fitted model. In other words, it is the optimal model. In order to choose the best ARDL (*p,q,r,s*), ARDL with different combinations of *p,q,r,s* = 1,2,3 will be used. The ARDL with the smallest AIC will be chosen as the optimal model. Once the optimal ARDL model has been chosen, the next step would be to conduct several diagnostic analyses on the model specified in this study. This involves testing if the residuals follow standard regularity conditions (homoskedasticity, no serial correlation and follows normal distribution). Further, stability tests (Ramsey RESET and Cusum test) will also be conducted to ensure that the estimated model is statistically robust.

5. EMPIRICAL RESULTS

Computation of the empirical results involved four steps as follows: First, the study examined for the order of integration of the variables using the Phillip-Perron (PP) test. Second, the UECM was estimated for the sample period. Third, diagnostic analysis was conducted to ensure that the residuals satisfied the standard regularity conditions and the estimated UECM is correctly specified. Finally, cointegration test using the Bounds Test for the sample period was done. If the test shows that the dependent and independent variables are cointegrated, then the long run and short run elasticities are computed using MICROFIT 4.1.

Table 4: Unit Root Test

Factor	**Level**	**1st Difference**	**Order of Integration**
RGDP	-2.536	--4.760 *	I (1)
ICTag	0.227	-4.132 *	I (1)
ICTman	0.198	--4.578 *	I (1)
ICTwho	-2.461 **		I (0)
ICTgov	-3.211**		I (0)

** Significant at 1 % level, ** Significant at 5 % level, *** Significant at 10 % level. All tests were conducted with trends and intercept.*

The result of the unit root test is given in Table 4. The test shows that except for ICTwho and ICTgov variables, all the other three variables have order of integration I(1). Normally, employment of the conventional cointegration method would require for all the factors to be or order I(1). In this study however, two factors is found to be or order I(0), thus these factors need to be excluded from this study. However, these factors are important for this study, thus employment of Bounds test is more justifiable as there will be no exclusion of variables. Following the unit root test, we estimate the UECM for the study. The UECM (p,q,r,s) was estimated using different lag length. Here, $p,q,r,s = \{1,2,3\}$. In this study, lag length higher than 2 was not used due to loss of degree of freedom. The estimated ARDL model is selected based on the Akaike Information Criterion (AIC). The optimal lag structure for the model (chosen based on the lowest AIC value) is given in Table 5 below.

Table 5: Optimal Lag Structure Using AIC

MODEL ARDL (p,q,r,s)	**AIC**
#ARDL [1,2,3,3]	***27.702***
ARDL [1,3,2,2]	31.324
ARDL [2,2,2,2]	34.211

 # The model with the optimal lag structure for the ARDL

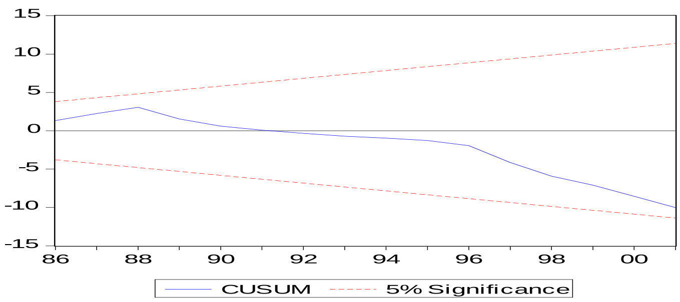
In this study, different diagnostic analysis was also conducted on the optimal specification to examine the robustness of the model. For this purpose, two types of diagnostic analysis were undertaken. First, Jarque-Bera test, Lagrange Multiplier test (LM), White's Heteroskedasticity test and Autoregressive Conditional Heteroskedastic (ARCH) test were done to determine whether the model is correctly specified. Second, the Ramsey Regression Specification Error Test (RESET) and Recursive Residual Test (RRT), also known as CUSUM test were done to examine the stability of the model. The results of the diagnostic analysis are presented in Table 5. Based on the Jarque-Bera test, there is sufficient evidence to conclude that the error is normally distributed at the 0.01 significance level. Results from the White's Heteroskedasticity test and the Autoregressive Conditional Heteroskedastic (ARCH) test showed that the residuals satisfy the standard regularity conditions. Result from the Ramsey RESET test showed that the estimated ARDL (1,2,3,3) model has no misspecification errors and is correctly specified. In addition, the result of the Recursive Residual Test (RRT) showed that the parameter of the estimated model is stable (the model is within the 5% critical line) for sample period A (refer to Figure 1).

Table 6: The ARDL Estimation and Diagnostic Analysis 1992 - 2006

Variables:	**Coefficients**	**t-stats**	**Diagnostics Results**	
C	112.7012	1.110	R-Squared	0.859
Δ *RGDP (-1)*	-1.9231	-0.925	Residual sum of squares	0.029
Δ *RGDP (-2)*	-1.7609	-1.060	Akaike Info. Criterion	21.066
Δ *ICTag (-1)*	-1.6575	-0.560	Durbin-Watson	2.607
Δ *ICTag (-2)*	-1.4220	-0.632	F-statistic	3.070 [0.089]
Δ *ICTman (-1)*	0.957	2.903*	Jarque Bera	0.038 [0.981]
Δ *ICTman (-2)*	0.229	0.937	LM test	5.282 [0.122]
Δ *ICTwho (-1)*	0.294	1.426**	White's Heteroskedasticity	14.824 [0.537]
Δ *ICTwho (-2)*	-1.803	-1.681	ARCH	5.615 [0.690]
Δ *ICTgov (-1)*	0.766	-1.288	Ramsey RESET	2.367 [0.124]
Δ *ICTgov (-2)*	0.766	-1.288		

*Notes: * and ** are significant at the 1% and 5% significance level. The p-value is given in* [ ].

Figure 1: CUSUM plot for the ARDL (1,2,3,3)



Once the ARDL model has been constructed, the next step involved computation of the cointegration between RGDP and its determinants. Table 7 provides the results for the cointegration test using the Bounds test.

Table 7: F-statistics for Bounds test

Computed F-statistic: 10.33 (0.01)	**Lower**	**Upper**
Critical Bound's value at 1%	5.17	6.36
Critical Bound's value at 5%	4.01	5.07
Critical Bound's value at 10%	3.47	4.45

The Critical bounds value was taken from Table F of Pesaran and Pesaran (1997)

The Bounds Test result showed that RGDP is cointegrated with its determinants, namely, ICTag, ICTman, ICTwho, and ICTgov - showing existence of a long run relationship between the variables.

Table 8: Long Run and Short Run Elasticities

Factors	**Short run**	**Long run**
ICTag	0.5402	1.7367
ICTman	0.2727*	0.901*
CTwho	0.6024 **	1.9365**
ICTgov	0.788	1.472

*** and * denotes statistically significant at 5 and 10% level, respectively.*

Table 8 shows the long run and short run elasticities for RGDP and its determinants. The result shows that the elasticity of ICT investment made by the agriculture sector (*ICTag*) is statistically insignificant both in the short run and long run. This implies that the agriculture sector in Malaysia has not gained from their technological investments. This is probably due to the fact that Malaysia's agro-based products are not produced using high-technology equipments or machineries. Most agro-based firms are still relying on conventional planting and harvesting approaches. Moreover, people in the agriculture sector are not well-integrated into the national ICT systems, mainly because they are less educated and are not motivated to utilize the existing systems for socio-economic benefits. This further exacerbates the fact that digital divide (i.e. ICT diffusion) in Malaysia is still wide as most farmers or people involved in the agriculture sector are in the rural states such as Pahang, Kedah, Perlis, Terengganu and Kelantan. ICT adoption in these states is relatively low as opposed to adoption in urban states (Kaliannan et al., 2007). In addition to that, only certain government agencies are pushing for technology utilization in the agriculture sector such as the Malaysian Agriculture Research and Development Institute (MARDI). This institute is responsible to spearhead ICT usage by the Malaysian agriculture sector and produce valued-added products, but our result shows this has a long way to go. This further augments the Ninth Malaysia Plan (ICT Chapter), which calls for greater usage of ICT within the agriculture sector of the economy.

Our empirical result also shows that the ICT investment made by the manufacturing sector (*ICTman*) in Malaysia is significant at 5% level in both short and long run. This shows that for every 1% increased ICT investment by the manufacturing sector, the economy grows by 0.27% in the short term, and further increases by 0.91% in the long run. This is not surprising given that the manufacturing sector in Malaysia is a prime user of ICT products and services such as the computer aided design and manufacturing systems (CAD/CAM), integrated logistics and supply chain systems (automated ware housing systems) and the use of financial electronic data interchange systems (FEDI), to support various business processes. Similar results are seen for the ICT investment made by the wholesale sector (*ICTwho*), as it is significant at 10% level in both short and long runs. For every 1% ICT investment by this sector, there is a linear growth in the economy by 0.6% (in the short term) and 1.9% (in the long term). The wholesale sector has benefited from ICT investments mainly through the use of FEDI systems. This sector (alongside the manufacturing) is expected to embark on greater use of technology to support mainstream supply chain processes in the form of radio-frequency-identification (RFID) systems in the very near future.

Ironically, ICT investment made by the government sector (*ICTgov*) is not significant in both the short and long run, despite the heavy investments made over the years. The issues that inhibit the government of Malaysia from reaping the maximum value from ICT investments include amongst others: (i) lack of consistent policies that support greater use of ICT within the public sector (ii) poor awareness and readiness amongst the civil force vis-à-vis usage of ICT systems (iii) the existences of various legacy systems that currently operate in silos – i.e. significant effort, time and costs are required to fully streamline the systems integration efforts within different government ministries and agencies (see for example; Kaliannan et al. 2007, The Star, 22nd January 2008).

6. Conclusion and Policy Suggestions

Based from the empirical evidences discussed above, it is evident that ICT investments undertaken in Malaysia have paid off – albeit at different scale in different economic sectors. ICT investments made by the private sector (with exception to the agriculture sector) seem to have contributed mainly to the country's growth as opposed to the government's investment. Whilst it is evident that Malaysia's ICT developments are benefiting the nation's welfare, we are in the opinion that more needs to be done in order to sustain and/or move forward in economic value chain. In this section of the paper, we provide suggestions on what else Malaysia can do to embrace the knowledge economy whilst increasing their economic prowess. The policy suggestions are focused at provision of better financial assistance to the private sector (i.e. for ICT related investments), fostering greater interaction between academic and the industry, greater support to enhance R&D activities.

6.1 Better Financing Opportunities for the Private Sector

There is a general tendency for financial institutions to shy away from financing ICT related initiatives (projects) carried out by the private sector. This needs to be addressed in order to fuel more innovative activities by the private sector that benefits the nation as a whole. Hence strategic policies targeted at increasing financing opportunities to the private sector are as follows:

- Creation of a legal system that allows financial institutions to obtain and enforce security for financing ICT related products and services by the private sector.
- Establishment of a risk-sharing loan programs by the government and the financial institution. This means that if a private firm obtains a loan from a commercial bank, and if the project fails, the risk is shared between the government and the commercial bank.
- Support for financial institutions to provide more equity and venture capital programs for ICT related initiatives undertaken by the private sector.

6.2 Academic-Industry Knowledge Transfer

Knowledge transfer from the academic research to industry is not a new phenomenon. The key issue here is effective management of such knowledge transfer in order to ensure successful outcome from the interaction. This is even more important for developing countries such as Malaysia. As the country is moving towards becoming a knowledge based economy, efficient knowledge transfer mechanisms are crucial to feed and sustain ICT-diffusion in the country. To this end, we propose the following:

- ***Increasing Human Mobility***
  Malaysia needs to facilitate mobility of human capital between academia and industries. One of the most mobile human capital would be the new PhD holders, who are in their preliminary career stage. Their placement with industries helps in knowledge transfer between both sectors, thus reinforcing network establishment between both sectors. To this end, Malaysia has to put in place strategic incentives for

both the industries and skilled PhD holders to participate in such knowledge transfer mechanism.

- ***Increasing knowledge management culture in the education sector***
  Knowledge management (KM) involves a set of tools and organizational practices that have not yet really been used in education sector to support and promote knowledge transfer (Yusuf and Nabeshima, 2007). KM in this context is about the government establishing incentives for education institutions to disclose their research findings and transferring it into intellectual property (IP) which can be used by the industries. Creation of a KM model is necessary at this juncture. The KM model would need to cover criterions such as transfer of IP to the industries, the definition of the field the IP is being used, and the granting of license outside the field of use to the academic sector.

- ***Increasing the Absorptive Capacity of SMEs in Malaysia***
  Generally, ICT usage is more prominent in larger firms as opposed to SMEs. Larger firms also tend to have more linkage with the academic sector. As highlighted by Yusuf and Nabeshima (2007), SMEs often have difficulties in optimizing linkages with the academic sector due to their inability to express their research and collaboration needs. They also often do not have the expertise or resources to manage such collaborative efforts. Thus Malaysia needs to address this issue by incentivising strategic knowledge transfer between academic research and SMEs. Such knowledge transfer can help to increase the utilization (hence investment) in ICT by SMEs.

6.3 Support to Enhance R&D Activities

ICT is a key driver for economic growth and competitiveness. Thus, Malaysia should focus on increasing the quantum and quality of ICT based products and services in the country. Government institutions should put equal emphasize in funding both basic and industrial research (especially, in new emerging areas of life sciences and ICT areas). Other related policies that should be in place in light of the above are as follows:

- Re-examining the fiscal incentives (tax credits and subsidies), and other financial support mechanism (funding for R&D-based infrastructure facilities) in national priority areas of research such as ICT, Biotechnology, Bioinformatics, Nanotechnology, and Mechatronics.

- Enhancing the flexibility of the public sector R&D funding needs to be increased – ability to shift funding to areas of increasing social and economic importance.

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