Investment in Information and Communication Technologies (ICT) and its Payoff in Malaysia

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Abstract

Information and communication technologies (ICT) have become the key drivers for socioeconomic development in recent years. This paper provides an empirical examination on the impact of ICT on Malaysian economic growth over the period 1975-2002 by using secondary data. Real GDP has been used as the dependent variable with three independent variables, namely, investment on ICT, non-ICT investment, and total labor employed in the economy. The unrestricted error correction method (UECM) and the cointegration bounds test revealed that the ICT had contributed positively to Malaysia's economic growth over the study period. The empirical result reflects the benefits gained from the immense ICT-based investment made in the country over the years. Further, several policy recommendations are discussed on how Malaysia can achieve better economic growth by leveraging of ICT.

Keywords: ICT, economic growth, bounds test, Malaysia, policies

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1. Introduction

Over the years, various studies have examined the contribution of ICT to a country's economic performance. Most of the empirical evidence showed that ICT had contributed significantly to economic growth in most developed economies, particularly in the second half of the 1990s. For example, Schreyer (2000) estimated the contribution of ICT to labor productivity in G-7 countries over the period 1990-1996. The empirical results from Schreyer (see to Table 1) showed that Germany had benefited significantly from ICT investment by achieving 2.1 percent average annual labor productivity growth over the period 1990-1996. The other six countries (Canada, France, Italy, Japan, the UK, and the US) had also achieved high labor productivity growth, ranging from 1.0 to 1.9 percent over the same period.

Table 1

ICT Contribution to Labor Productivity in G-7 Countries, 1990-1996

Country	Labor Productivity Average Annual Growth
Canada	1.3
France	1.6
Germany	2.1
Italy	1.9
Japan	1.9
UK	1.4
US	1.0

Source: Schreyer (2000, Table 6, p. 19).

The OECD (2001) study highlighted that the ICT manufacturing sectors in Finland, Ireland, and Korea contributed to a strong labor productivity growth of 4 percent in the late 1990s. Few studies highlighted the benefits of ICT at the micro level, that is, at the firm or industry level. For example, Gurbaxani and Whang (1991) and Bresnahan (1997) showed that an organization that increases its ICT-based equipment for its workers (also called capital deepening) will experience increased labor efficiency and productivity. Also studies by Brynjolfsson and Hitt (1995), Hitt and Brynjolfsson (1996), Brynjolfsson and Yang (1996), and Brynjolfsson and Hitt (2000) have established that ICT utilization helps firms and businesses to expand their market share or economies of scale by way of responding quickly to customers' demand and serving more customized products and services.

While the literature on ICT and economic growth is abundant, much of the work is based on the experience of the developed countries. There have not been many studies conducted on a developing country such as Malaysia. While the development of ICT in Malaysia is still at the growing stage, nevertheless quantification of the payoffs from ICT investments made in the country may have important national policy implications. Hence, the present study aims to examine the impact of ICT investment on economic growth over the period 1975-2002. The rest of the paper is organized as follows. Section two provides the literature review on the link between ICT and economic growth, followed by the discussion on the data and methodology in section three. Section four provides the empirical results, and section five provides the conclusions and policy remarks.

2. Link between ICT and Economic Growth: Literature Review

The literature concerning ICT investment and economic growth is vast and diverse. Generally, two different measurement methods have been used in most of the studies, that is, the production function approach and the growth accounting framework. While studies conducted in the late 1980s and early 1990s have reported negative or mixed results (Roach 1987; Strassman 1990; Morrison and Berndt 1991; Berndt et al. 1992; Loveman 1994), more recent studies have established that ICT investment yielded higher returns than non-ICT investment in the developed countries (Lichtenberg 1995; Brynjolffson and Hitt 1995; Lehr and Lichtenberg 1999; Oliner and Sichel 2000). However, studies of developing countries have found an insignificant relationship between ICT investment and economic growth (Dewan and Kraemer 1998; Plice and Kraemer 2001; Ng and Chang 2003).

Solow (1957) was one of the pioneers in this context. Solow (1957) employed the aggregate production function to measure the contribution of technological change on economic growth in US firms over the period 1909-1949. In this approach, a single output is expressed as a function of technology, capital, and labor inputs. The author concluded that economic growth in the United States during the sample period was largely attributed to the "technological change" factor rather than the labor or capital factor.

Solow's conclusion sparked wide debate among scholars and economists regarding the impact of technological change on output growth, largely because of the assumption that technology is exogenous to output growth. Studies conducted in the subsequent years have used the new growth theory (Romer 1986) to gauge the contribution of ICT investment to economic growth. Studies that used a sample period prior to the 1990s have concluded that ICT investment had no significant impact on the growth of the economy. However, studies done after the 1990s showed different results.

Lau and Tokutsu (1992) investigated the contribution of ICT investment to economic growth in the United States using annual time series data for the period 1960-1990. They estimated a translog unit-cost function with three inputs, namely, computer capital, non-computer capital, and labor. The empirical result showed that nearly half of the growth in the aggregate national output in the United States was attributed to ICT investment (that is, computer capital) rather than to non-ICT investment (non-computer capital) or labor.

Niininen (1998) used the neoclassical growth accounting framework to examine how investment in computers contributes to economic growth in Finland. The author used the standard growth equation and decomposed economic growth between 1983 and 1996 into portions that may be attributed to capital, labor, and multifactor productivity. Subsequently, this model was augmented to include the effects of ICT on growth, that is, by examining the contribution of the stock of computer hardware, software, and computer labor to growth. The results indicated that, compared to other inputs, ICT exerts a strong influence on real growth in output. As for the other components, the contribution of labor was negative, while that of multifactor productivity was found to be more than the total growth rate.

Daveri (2000) updated Schreyer's (1999) research and extended it to another eleven OECD countries. Apart from using similar data to that in Schreyer's work, Daveri also added software to ICT capital. The author found similar results as those of Schreyer (2000); that is, ICT added substantially to national output growth during the later part of the 1990s for all the sample countries, though the magnitudes differ greatly across the countries. The author concluded that all the sample countries have received virtually the same boost to growth from ICT investment.

Poh (2001) investigated the impact of ICT investment on overall productivity in Singapore by estimating the Cobb-Douglas production function that separated capital stock into an ICT component and a non-ICT component. The dependent variable was economic growth (the aggregate national GDP in constant price), while the independent variables were labor inputs measured in number of work hours, ICT capital stock in constant price, non-ICT capital stock in constant price, and TFP growth rate. The study period was from 1977 to 1997. The estimation result for this period showed that ICT capital has generated a rate of return that significantly exceeded the return on non-ICT capital. The author concluded that ICT investment in Singapore provided significant payoff in terms of productivity gain.

Oulton (2001) estimated the contribution of ICT investment to economic growth in the UK over the years 1989-1998, using the growth accounting framework. In this study, ICT capital was segregated into computers, software, telecommunications equipment, and semiconductors. The empirical estimation showed that GDP growth has been significantly understated, particularly since 1994, in the UK. From 1989 to 1998, ICT capital contributed one-fifth to the overall GDP growth in the UK. It was also found that since 1989, 55 percent of capital deepening has been contributed by ICT capital and 90 percent since 1994. Subsequently, ICT capital deepening was found to account for nearly 25 percent of the labor productivity growth during the period 1989-1998 and 48 percent during the period 1994-1998.

Colecchia and Schreyer (2002) compared the impact of ICT capital accumulation on output growth in Australia, Canada, Finland, France, Germany, Italy, Japan, the UK and the US over the period 1980-2000. The results showed that during the study period, ICT contributed between 0.2 and 0.5 percentage points per year to economic growth, depending on the country. However, during the second half of the 1990s, this contribution rose to 0.3 to 0.9 percent per year. The authors also found that despite differences between countries, the United States has not been alone in benefiting from the positive effects of ICT capital investment on economic growth nor was the United States the sole country to experience an acceleration of these effects.

More recently, Kim (2003) examined the impact of ICT on productivity and economic growth in Korea during 1971 to 2000. Here, the growth contributions from the standard input factors, specifically, ICT capital inputs, and the business cycle effect, are computed on the basis of the growth accounting framework. The study also examined the source of productivity growth using the extended growth accounting model, drawing attention to the role that ICT and knowledge capital have played. The results showed that ICT capital contributed 16.3 percent to the output growth and has a strong positive effect on the growth of labor productivity in the long run.

In total, the issue of ICT and economic growth has received much attention with respect to the developed countries as compared to the developing countries. This is even more visible for the US-based studies. The literature showed that most developed countries experienced significant returns from ICT investment, particularly during the mid-1990s. In general, the production function approach and growth accounting framework have been widely used to quantify the contribution of ICT to economic growth; these methods, however, are not free from criticism.

As far as the growth accounting is concerned, one common criticism is that, while this method effectively quantifies the proximate sources of growth, it cannot provide a deeper explanation for why certain events or situations occurred. In addition, a number of assumptions are required for the successful implementation of growth accounting calculations. For example, the assumptions of constant returns to scale and competitive markets are often imposed in the estimation of factor shares. Pohjola (2002) pointed out that the growth accounting framework only yields a mechanical decomposition of the growth of output into growth of inputs and multifactor productivity. It does not explain economic growth by relating the changes in inputs and productivity to the more fundamental elements of the economy, such as technology and government policies.

Meanwhile, the production function method does not provide much concentration on the issue of time series problems, such as the problem of spurious regression. More specifically, the existence of non-stationary and stationary time series variables is often neglected. As highlighted by Granger and Newbold (1974), if this assumption is not satisfied, the estimated results may be spurious. Lee and Gholami (2001) noted that, while non-stationary variables may show no cointegration, an assumption is made that there is no long-run relationship between the variables. However, the ordinary least square regression results may still show a significant relationship among the variables.

This study examines the relationships between ICT investment and economic growth in Malaysia using a robust cointegration and error correction method called the bounds test (Pesaran et al. 2001) and the unrestricted error correction method (UECM) (Banerjee et al. 1998). Most past studies have not concentrated much on the cointegration issue. This may be because the conventional cointegration method, such as found in Engel and Granger (1988) and Johansen and Juselius (1990), requires a large sample size. Moreover, the order of the integration needs to be either I (0) or I (1). However, this is not a necessary prerequisite for the case for the UECM approach. In this method, the order of integration can be either I (0) (stationary) or I (1) (non-stationary). 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 a large sample size constitutes studies that use a sample period of at least 50 years.

3. Methodology of the Study

3.1 *Data*

The data for this study was gathered from various reports published by the Malaysian Department of Statistics; the reports are as follows:

i) Survey of Industries in Malaysia (1970-2003)
ii) Annual National Products and Expenditures (1970-2003)
iii) National Accounts of Malaysia (1970-2003)
iv) Annual Statistics of Manufacturing Industries (1970-2003)
v) The Labour Force Survey Report (1970-2003)

All variables are measured in Malaysian Ringgit at current price. Due to difficulty in obtaining ICT investment data as a total sum figure, the total ICT investment figure was computed from investment in thirteen ICT-based products. This method was adopted from the recommendations given in the Malaysian Standard Industrial Classification (MSIC) 2000. Table 2 provides the components of ICT product investment used in this study.

Table 2

ICT Investment Products Classification MSIC 2000

Commodity Division (MSIC) 2000 Classification	Industry/Product Description
75	Office machinery and automatic data processing equipment
76	Telecommunication, sound recording, reproducing equipment
751	Office machines
752	Automatic data processing machines
759	Parts and accessories for other automatic machines
761	Television receivers
762	Radio broadcast receivers
763	Gramophones, dictating machine, sound recorders
764	Telecommunication equipment and parts
771	Electrical power machinery and parts
772	Electrical apparatus, resistors, and switchboards
773	Equipment for distributing electricity
774	Electro-medical and radiological apparatus

Source: ICT Survey Report (2003), Department of Statistics, Malaysia.

Data on non-ICT investment variable consists of capital investment made into land and buildings, general administration, health, economic services, education, and road and transportation services. Finally, data on the number of laborers employed in the country represents the total number of workers employed in Malaysia over the study period. This is denoted by millions of workers.

3.2 *Methodology*

The model of this study is as follows:

$$RDGP_1 = \beta_0 + \beta_1 ICT + \beta_2 NICT_1 \ \beta_3 L_1 + \varepsilon_1 \qquad (1)$$

where

RGDP = real gross domestic product
ICT = ICT investment
NICT = non-ICT investment
L = labour employed
ε = error term

In this paper, a new econometric formulation called the unrestricted error correction method (UECM) is used (Banerjee et al. 1998) to model the impact of ICT investment on Malaysia's economic growth over the period 1975-2002. The UECM is a new approach to error correction and is within the framework of autoregressive-distributed lag (ARDL). This method has several advantages compared to the conventional error correction. According to Pesaran and Shin (1999), the ARDL-based estimators of the long-run and short-run coefficients are super-consistent in a small sample size. Second, the ARDL method of cointegration analysis is unbiased and efficient. This method can estimate the long-run and short-run components of the model simultaneously, thus removing problems associated with omitted variables and autocorrelations. Finally, the ARDL method can distinguish between the dependent and the independent variables much more effectively (Narayan and Narayan 2003).

Further, a new cointegration test called the bounds test (Pesaran et al. 2001) is used to examine whether Malaysia's economic growth is cointegrated with its determinants over the study period. Similar to UECM, the bounds test has its own advantages over the commonly used cointegration tests such as the Engle-Granger (1987) and Johansen-Juselius (1990) methods.

First, the bounds test can be employed regardless of whether the underlying regressors are purely $I(0)$ or $I(1)$, or mutually cointegrated. Second, the bounds test works well for studies with small samples. According to Mah (2000), this test is not plagued by small sample bias as are the traditional cointegration tests. While relatively new, the bounds test and UECM method have been applied widely in recent studies, such as in the studies by Mah (2000), Siddiki (2000), Alias et al. (2002), Tang and Nair (2002), Nair et al. (2002), Narayan and Narayan (2003), and Narayan and Smyth (2003). The empirical evidence in these studies showed robust analysis of long-run relationships between the dependent and independent variables.

3.3 *Unit Root Test*

The order of integration of the variables was done prior to examining the long-run impact of ICT investment on Malaysia's economic growth. The stationarity test was investigated using the unit root test. Dickey and Fuller (1979) noted that when a non-stationary time series is regressed on another non-stationary time series, the standard *t* and *F* testing procedures are not valid. There are two popular approaches to determine unit roots in a set of variables: the Augmented Dickey-Fuller Test (ADF) and the Phillip-Perron (PP) Test. In this study, we have used the Phillip-Perron Test due to its less restrictive assumption on the residuals; that is, the Phillip Perron Test considers the existence of serial correlation in the errors and robust against hetereoskedasticity in errors.

3.4 *The ARDL Framework*

The augmented ARDL ($p,\ q_1,\ q_2, \ldots\ldots\ q_k$) model can be written as follows (Pesaran et al. 2001):

$$\Omega(L,\ p)\ y_1 = \alpha_0 + \sum_{i=1}^{k} \beta_i(L,q_i)x_{it} + \delta^{\cdot}\ w_1 + \mu_t \tag{2}$$

where

$$\Omega(L,\ p) = 1 - \Omega_1\ \delta_1\ L^1 - \Omega_2\ \delta_2\ L^2 - \ldots\ldots - \Omega_p L^p \tag{3}$$

$$\beta_i\ (L,\ q_i) = \beta_i + \beta_{i\ 1} L + \beta_{i\ 2}\ L^2 + \ldots + \beta_i\ q_i\ L^{qi},\ i = 1,2, \ldots k \tag{4}$$

Here, y_t is the dependent variable; α_0 is a constant; L is a lag operator such that $Ly_t = y_{t-1}$; and w_t is a $s\ x\ 1$ vector of deterministic variables such as seasonal dummies, time trends, or exogenous variables with fixed lags. The x_{it} in equation (2) is the i independent variable where $i = 1,2, \ldots k$. In the long run, we have $y_t = y_{t-1} = \ldots\ldots = y_{t-p}$; $xit = x_{i,t-1} = \ldots = x_{tit-q}$, where x_{tit-q} denotes the q^{th} lag of the i^{th} variable. The long-run equation with respect to the constant term can be written as follows:

$$y = \alpha_0 + \sum_{i=1}^{k} \beta_i x_i + \delta^{\cdot} w_1 + v_t \tag{5}$$

$$\Omega = \frac{\mathrm{a}}{\Omega(1,p)} \tag{6}$$

The long-run coefficients for a response of y_t to a unit change in x_{it} are estimated by

$$\beta i = \frac{\hat{\beta}(1,\hat{q}_i)}{\Omega(1,\hat{p})} = \frac{\hat{\beta}_{i0} + \hat{\beta}_{i1} + \ldots . \hat{\beta} + _{i\hat{q}}}{1 - \hat{\Omega}_1 - \hat{\Omega}_2 - \ldots\ldots - \hat{\Omega}_{\hat{p}}} \qquad i = 1,2,\ldots,k \tag{6}$$

where $\hat{p}$ and $\hat{q}_1$, $i = 1,2,\ldots,k$ are the selected (estimated) values of p and q_i, $i = 1,2,\ldots,$k. The long-run coefficients associated with the determinant variables (with fixed lags) are estimated by the following:

$$\hat{\delta} = \frac{\delta(\hat{p}, \hat{q}_1, \hat{q}_2, \ldots, \hat{q}_k)}{1 - \hat{\Omega}_1 - \hat{\Omega}_2 - \ldots\ldots - \hat{\Omega}_{\hat{p}}} \tag{7}$$

where $\delta(\hat{p}, \hat{q}_1, \hat{q}_2, \ldots, \hat{q}_k)$ depicts the ordinary least squares estimates of δ in Equation (7)—the selected ARDL model. Further, the error correction (EC) representation of the ARDL $(\hat{p}, \hat{q}_1, \hat{q}_2, \ldots, \hat{q}_k)$ model can be obtained by writing Equation (2) in terms of the lagged levels and the first differences of y_t, x_{1t}, $x2_t$, $\ldots$, x_{kt} and w_t:

$$\Delta y_1 = \Delta\alpha_o - \sum_{j=1}^{\hat{p}-1} \Omega^*_j \Delta y_{t-j} - \sum_{i=1}^{k} \beta_{i0}\Delta x_{it} - \sum_{i=1}^{k}\sum_{j=1}^{q_t-1} \beta^*_{ij}\,\Delta x_{i,\,t-j} + \delta' w_t -$$

$$\Omega(1, \hat{p}) ECM_{t-1} + \mu_t \tag{8}$$

where ECM_t is the correction term defined by

$$ECM_t = y_t - \hat{\alpha} - \sum_{i=1}^{k} \hat{\beta}_i x_{it} - \delta' w_t \tag{9}$$

where Δ is the first difference operator; Ω^*_j, β^*_{ij} and δ' are the coefficients relating to the short-run dynamics of the model. Further, in the initial investigation of a long-run relationship between the dependent and its determinants, a two-step procedure will be employed to estimate the short-run and long-run parameters of the variables, using Equation 10. However, note that the estimation will be undertaken only if the long-run relationship is established in the first step. In this study, the following ARDL model will be specified:

$$\Delta RGDP_t = \alpha_{0ICT} + \sum_{i=1}^{p} \beta_{iICT}\,\Delta RGDP_{t-i} + \sum_{j=1}^{q} \delta_{iICT}\,\Delta ICT_{t-i} + \sum_{k=0}^{r} \omega_{iICT}\,\Delta NICT_{t-i} + \sum_{l=1}^{s} \chi_{iICT}\Delta L_{t-i} \tag{10}$$

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 among the variables is as follows:

$$H_0: \lambda_{1RGDP} = \lambda_{2RGDP} = \lambda_{3RGDP} = \lambda_{4RGDP} = 0$$
$$H_1: \lambda_{1RGDP} \neq \lambda_{2RGDP} \neq \lambda_{3RGDP} \neq \lambda_{4RGDP} \neq 0$$

The *F-test* has a nonstandard 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 nonstandard 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 the computed *F* statistics falls inside the upper and lower bounds, a conclusive inference cannot be made without further tests.

3.5 *Optimal Lag Length Selection and Diagnostic Analysis*

Obtaining the appropriate lag length to be included in the model is important as shortage of lag lengths may lead to misspecification of the model and possibly result in serial correlation of the residuals. 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). This study has used AIC for lag selection. The optimal lag length selection. The approach shows that if one model stands out among the others in terms 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 for the best ARDL (p,q,r,s) to be chosen, 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 step involves testing to determine whether the residuals follow standard regularity conditions (homoskedasticity, no serial correlation and follows normal distribution). Further, stability tests (the Ramsey RESERT and the Cusum test) will also be conducted to ensure that the estimated model is statistically robust.

4. Empirical Results

Computation of the empirical results involved four steps. 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, a cointegration test, using the bounds test for the sample period, was performed. 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 3

Unit Root Test

Factor	Level	1st Difference	Order of Integration
RGDP	-1.956	-4.760 *	I (1)
ICT	0.827	-4.132 *	I (1)
NICT	0.098	-4.578 *	I (1)
L	3.267 **		I (0)

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

The results of the unit root test are given in Table 3. The test shows that, except for labor employed (L), all the three variables have order of integration I(1). Normally, employment of the conventional cointegration method would require all the factors to be of order I(1). In this study, however, labor employed is found to be of order I(0); thus, labor employed is supposed to be excluded from this study. Since this is not possible, as labor is an important variable in measuring economic growth of a country (Parkins 2001), employment of the bounds test is more justifiable.

Following the unit root test, we estimate the UECM for the study. A different lag length was used to estimate the UECM (p,q,r,s). Here, $p,q,r,s = \{1,2,3\}$. In this study, lag length higher than 3 was not used due to loss of the 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 4 below.

In this study, different diagnostic analyses were also conducted on the optimal specification to examine the robustness of the model. For this purpose, two types of diagnostic analyses were undertaken. First, the Jarque-Bera Test, the Lagrange Multiplier Test (LM), White's Heteroskedasticity Test, and the Autoregressive Conditional Heteroskedastic (ARCH) Test were administered to determine whether the model is correctly specified. Second, the Ramsey Regression Specification Error Test (RESET)

Table 4

Optimal Lag Structure Using AIC

MODEL ARDL (*p,q,r,s*)	AIC
#ARDL [1,2,3,3]	29.904
ARDL [1,3,2,2]	32.463
ARDL [2,2,2,2]	33.826

The model with the optimal lag structure for the ARDL.

and Recursive Residual Test (RRT), also known as the CUSUM Test, were conducted 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 1.0 percent 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.

Results from the Ramsey Regression Specification Error Test (RESET) showed that the estimated ARDL (1,2,3,3) model has no misspecification errors and is correctly specified. In addition, the results of the Recursive Residual Test (RRT) showed that the parameter of the estimated model, which is within the 5 percent critical line, is stable for sample period A (see to Figure 1).

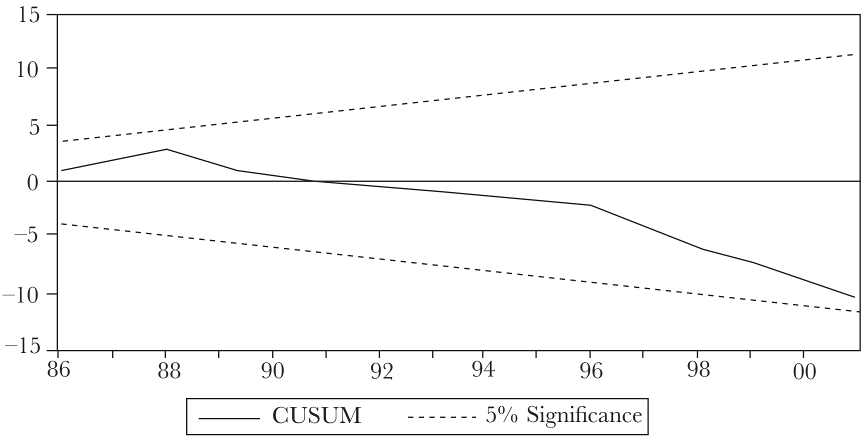

Figure 1. CUSUM Plot for the ARDL (1,2,3,3)

Table 5

The Estimated ARDL (1,2,3,3)

Dependent variable: Δ RGDP
Sample period: 1975-2002

Variables:	Coefficients	t-statistics
C	112.7012	1.110
Δ RGDP (-1)	-1.9231	-0.925
Δ RGDP (-2)	-1.7609	-1.060
Δ ICT (-1)	-1.6575	-0.560
Δ ICT (-2)	-1.4220	-0.632
Δ ICT (-2)	0.58099	2.055
Δ ICT (-2)	0.77261	3.447
Δ L (-1)	-4.1853	-4.698
Δ L (-2)	-7.0048	-0.980

*** is significant at 5 percent significance level.*

Diagnostic Analysis:

R-Squared:	0.8854
Residual sum of squares:	0.0436
Akaike Info. Criterion:	29.9045
Durbin-Watson:	2.3836
F-statistic:	6.5381 (0.02)
Jarque bera:	0.0587 (0.971)
LM test:	1.7955 (0.180)
Autoregressive Conditional Heteroskedasticity:	0.0994 (0.753)
Ramsey RESET:	0.9330 (0.334)

Once the ARDL model has been constructed, the next step involved computation of the cointegration between RGDP and its determinants. Table 6 provides the results for the cointegration test using the bounds test.

Table 6

F-Statistics for Bounds Test

Computed F-statistic: 11.392 (0.01)	Lower	Upper
Critical Bound's value at 1%	3.063	4.084
Critical Bound's value at 5%	3.539	4.667
Critical Bound's value at 10%	4.617	5.786

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

The bounds test results showed that RGDP is cointegrated with its determinants—ICT, NICT, and L—showing existence of a long-run relationship between the variables.

Table 7

Long Run and Short Run Elasticities

Factors	Short-Run	Long-Run
ICT	0.3085 (0.09)***	1.0426 (0.05)**
NICT	-0.1118 (0.72)	-1.2678 (0.07)***
L	-0.5453 (0.37)	1.0616 (0.03)**

** and *** denote statistically significant at 5 and 10 percent level, respectively.

Table 7 shows the long-run and short-run elasticities for RGDP with respect to ICT, NICT, and L. The results provided in Table 6 show that over the period 1975-2002, the elasticity of ICT investment is statistically significant at 10 percent in the short run and 5 percent in the long run. The results imply that a 1.0 percent growth in ICT investment in Malaysia expands the economy by 0.31 percent in the short run and 1.04 percent in the long run. Note that the contribution of ICT investment to Malaysia's economic growth in the long run shows existence of an increasing returns to scale.

Non-ICT investment, on the other hand, has a negative and insignificant relationship with Malaysia's economic growth in the short run and a negative but significant relationship in the long run. Labor also has a negative and insignificant relationship with Malaysia's economic growth in the short run, and a positive and significant relationship in the long run.

5. Conclusions and Policy Implications

The empirical results show that, in the long run, economic growth was cointegrated with ICT investment, non-ICT investment, and the labor force. The result of the coefficient estimation showed ICT investment as the most significant factor that drives economic growth in Malaysia over the period 1975-2002. The empirical result coincides with the empirical evidence obtained in some countries; for example, Colecchia and Schreyer (2002) found that over the period 1980-2000, ICT contributed between 0.3 to 0.9 percent to economic growth in several OECD countries.

However, the empirical results in this study contradict the results obtained in studies conducted on developing countries. For example, the studies by Kraemer and Dedrick (1994), Dewan and Kraemer (1998), and Ng and Chang (1999) found negative effects of ICT investment on economic growth in some developing countries. More recently, Dewan and Kraemer (2000) found that over the period 1985-1993, the returns on ICT investments were positive and statistically significant for developed countries, but insignificant for developing countries.

During the early years, mainly export of commodity-based products drove Malaysia's economic growth. In the early 1970s, as a remedy to unemployment problems caused by reduction of job opportunities in the agriculture sector, Malaysia embraced the industrialization development economic policies. The mid-1980s saw emergence of heavy industrialization, such as Motorola, Intel, and Nokia. Apart from this, Malaysia also embarked on a privatization drive, which saw Telekom Malaysia becoming privatized in 1984, thus, spurring growth of telecommunication industry in the country. More and more ICT-based industries emerged in later years. Telecommunication companies such as Maxis, Celcom, DIGI, and TimeCell were established in the early 1990s, inducing high growth in mobile phone users in the country, especially after the mid-1990s.

During this period, Malaysia also provided high concentration on research and development (R&D) activities. As part of the efforts to make R&D more relevant to the industries, the government established a number of public research institutes that provide the required organizational and administrative support. For example, institutes such as Malaysian Agriculture Research and Development Institute (MARDI) and Standards & Industrial Research Institute of Malaysia (SIRIM) undertook steps to establish a contract research management system that promotes R&D services in the industries. Further, the government also provided increased R&D funding to strengthen development of industry-oriented technology. For example, the Intensification of Research in Priority Areas (IRPA) research grant program provided research funding for R&D at the industry level. In early 1990, a total of RM318 million was distributed for industrial research in the country (Sixth Malaysian Plan 1991).

In short, heavy industrialization policies and strategic efforts by the government have induced high ICT capital investment over the years. Although the empirical results showed Malaysia benefiting from ICT investment in recent years, one important question, however, remains unanswered. As is widely known, Malaysia is still a country that integrates foreign technology into domestic applications; whereas developed economies are moving ahead of developing countries in terms of technological development, they are innovators in the new economy.

Riding on the eagerness to "catch up" with the technology leaders, Malaysia launched the Multimedia Super Corridor in the effort to overcome technological barriers in local development. Although high ICT investment in most sectors of the economy has seen substantial benefits, in terms of higher productivity and economic growth, the question is whether Malaysia can sustain economic competitiveness factored by ICT on a continuous basis. In order to enhance the role of ICT in economic expansion, new policies that necessitate the formation of critical mass in ICT application need to be implemented in the country.

First, a great amount of room exists for improvement in ICT diffusion in Malaysia, if the future economic growth is to be leveraged against ICT. For example, Malaysia needs to invest in advanced ICT infrastructure that supports rapid ICT diffusion in the country. The development of modern, technically efficient and cost-effective ICT infrastructure is of critical importance to the establishment of effective communication services in Malaysia. In particular, Malaysia needs to invest significantly in providing universal access to ICT at both rural and urban areas by concentrating on computer ownership in each home. This can be done with provision of interest-free loans for computers or other forms of subsidies for purchase of computers. This would stimulate computer buying among the people. Further, provision of low-cost Internet access is also necessary, which would ensure more Internet penetration in the country. At this moment, Internet penetration in Malaysia is rather slow, largely because of the high cost of access. The country can achieve improvement in this area by way of investing in broadband technology and providing it at subsidized cost to consumers.

Second, diffusion of ICT would not progress without having a labor force with adequate knowledge and skills. To this end, Malaysia needs to ensure that the people have the right knowledge and skill in order to absorb ICT diffusion. Thus, the country needs to upgrade its human capital by investing in ICT-based education and training programs. Although the current education policy has introduced "learning through ICT," the policies have to ensure that formal education systems respond in a cost-effective way to changing requirements. More specifically, the education policies need to introduce ICT-based education to students during early childhood and not focus on a specific group of students only; at present, for example, Malaysia has introduced ICT-based education to primary one and secondary one students only. Malaysia should also invest in an education system that puts greater attention on school-to-work transition. As the experience of Austria, Denmark, Germany, and Switzerland shows, "dual" apprenticeship systems can be successful in integrating young students into employment (Pilat, 2002). In short, Malaysia needs to reexamine its education policies by integrating ICT-based skill-building systems into all levels of education. More importantly, Malaysia has to cater to a new economy that requires knowledgeable and competitive human capital.

Third, Malaysia should invest in an efficient and effective electronic-based government services or "e-government." The government is the biggest service provider in a country. Specifically, the government should create e-government portals or websites that follow a standard format instead of designing individual website layouts. The website standard needs to be controlled or monitored by an individual agency and, as a result, two main implications would become evident. First, the websites will follow the best practice method, thus ensuring higher quality of electronic services; for example, the website standard would need to emphasize the importance of updating regular information on the website. Further, this approach would also integrate various government departments into an integrated public services portal, thus closing the ICT gap between the government and the private sector.

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