Impact of Innovation on Economic Growth: Evidence from Malaysia

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Abstract: This study empirically investigates the effect of innovation on economic growth using the neoclassical economic growth model. Embarking from the traditional labour growth, physical capital and human capital framework, innovation is postulated to be the main driver for robust economic growth. Using time series techniques, we discover very attention-grabbing findings that highlight the impact of innovation on economic growth for Malaysia. First, the innovation measured by the quantity of a total number of a patent application is statistically insignificant. The result is robust for various innovation measurements, including total local patent application and total foreign patent application. Interestingly, switching to total patent grant instead of a total number of patent application (local or foreign), the empirical result shows a significant impact on economic growth. The finding indirectly reveals the crucial impact of quality innovation rather than the quantity concern. Neglecting both quality and the commercial-isation process of these new technologies may not solve the rigidity of knowledge-commercialisation paradox. Finally, we test for the prominent institutional quality in mediating economic growth under a knowledge-based economy. The interaction between institutional quality and the total patent grant has significantly accelerated the role of innovation channel to economic growth. The empirical findings imply that inadequacy of innovative technology flow over the long term has a detrimental effect on national innovative capacity. Thus, the innovation-economic growth nexus needs to be complemented with a good institutional quality framework, skilled human capital and broader networking to commercialise the innovative product to ensure that the innovation activities promote economic growth.

Keywords: ARDL, economic growth, innovation, institutions, quality innovation
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1. Introduction

Sustainable economic growth issue has been a central discussion in the economic development debate. Apart from proposing growth determinants, finding a new feasible growth driver is of utmost importance. Some economists have argued that policies, which embrace openness, competition and productivity improvement, will promote sustainable growth. Others have countered that the strategy should emphasise domestic innovation activity – and preferably high-tech manufacturing. Malaysia, as an emerging economy, also redefines its growth strategy via the New Economic Model (NEM) in 2010 and the Economic Transformation Program by identifying the main key areas to stimulate economic growth. Nevertheless, the question of maintaining high economic growth has been a continuous academic discourse significant subject of ongoing debate.[1]

Recent economic growth theories postulate that a new range of innovative products or business model as an outcome of continuous research and innovation is another primary catalyst of productivity and economic growth. Any move towards promoting innovation should be a priority. Figure 1 depicts that the innovation activities of upper-middle-income countries are catching up with the high-income countries
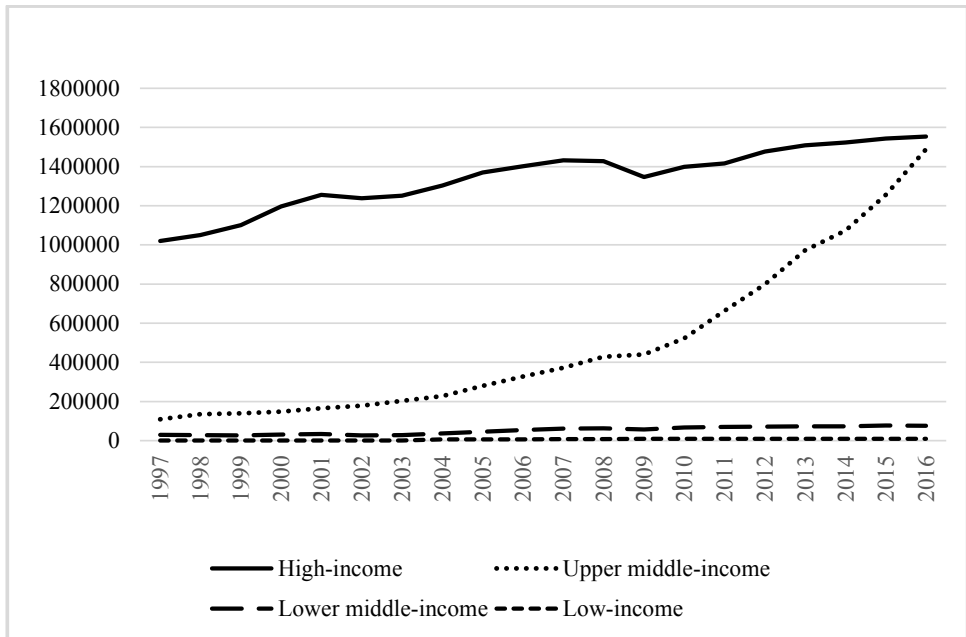

Figure 1. Innovations (total patent application) at different income levels

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[1] The goal of the NEM is to "transform the Malaysian economy to become one with high incomes and quality growth" by 2020. At the time of the plan's unveiling in 2010, per capita annual income in Malaysia stood at US$7,000, under the plan that figure would more than double to US$15,000. The keys to the plan are "high income, sustainability and inclusiveness".

where these two income levels converge to a similar point. In terms of Malaysian innovation performance compared to the world, Malaysia was ranked 35th in 2018 and 37th in 2017 by the World Economic Forum (WEF) based on the Global Innovation Index (GII). The indicator suggests that Malaysia's innovation has improved comparatively among its peers, but to be in the select group of high-income countries, improvement of innovation will be necessary and the way to move forward.

The dynamic relationship between innovation and economic growth can be traced back to Schumpeter (1939), who argued that competition through innovation and education are important in ensuring economic growth; and these assumptions are supported by empirical studies (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005). According to Schumpeter, innovation which manifest itself in the shape of investment is a driver of economic development. Investment, in turn, is driven by profit expectations. Thus, if a country wants to promote economic growth, then a country should find a way to turn on profit expectations of investment. Another strand of theoretical discussion is the endogenous growth model developed by Romer (1986), where the economic growth is endogenously determined and is influenced by agents' decisions to maximise profits, taking into consideration aspects related to entrepreneurship by modelling the innovation process. In the endogenous growth literature, many models (Grossman & Helpman, 1991; Romer, 1990) illustrate the function of innovation as a growth engine, and government plays an important role in achieving an optimum level of innovation and R&D. The distinction between Schumpeterian models (Aghion & Howitt, 1992) and Romerian models rest on how they interpret innovation and what drives innovation (quality ladder vs product variety expansion).

This paper examines the effect of innovation on economic growth in Malaysia using time series analysis. According to Mc Morrow and Röger (2009), an economy's agility to develop cutting edge technologies and adapt to a fast changing technological environment is crucial to its prospects of improving people's welfare and creating economic prosperity. This study contributes to the literature in three important aspects. First, we utilise the total patent applications and total patent grants as innovation measurements which are both widely used in the literature. However, in this study, we postulate that the innovation measured by the quantity of total number of patent application is not a good choice for innovation proxy. Therefore, this study uses total patent granted which indirectly reveals the crucial impact of the quality innovation instead of total number of patent application which is more of quantity measurement, has shown robust significant impact on economic growth. Second, the autoregressive distributed lag (ARDL) model is applied to evaluate the effect of innovation on economic growth. The ARDL bounds testing methodology develop by Pesaran, Shin and Smith (2001) has few advantages over other cointegration testing. Apart from its effiency to handle the small sample size, the ARDL could estimate a mixture of order of integration, i.e. integration of level [I(0)] and first difference [I(1)]. The estimation uses a single-equation set-up which makes the estimation procedure less complicated. Another advantage is that the interpretation of each variable can be dedicated to different lag-lengths as they enter the model. Third, this study not only uses a linear ARDL model, but it also uses the quantile regression to observe information on the asymmetric and

non-monotonic effects of the conditional variables on the dependent variable. It can capture the impact of rapid changes in innovation on the direction and magnitude of economic performance across different quantiles. Fourth, this study also compares the relative importance of foreign and local innovations in influencing economic growth. Last, this study also examines the role of institutional quality in mediating the effect of innovation-economic growth nexus.

The organisation of the study is as follows. Section 2 delves into the literature. Section 3 lays out the econometric estimation technique and the data sources. Section 4 focuses on the empirical results. Finally, Section 5 concludes.

2. Literature Review

A well-documented literature among development economists suggests that innovation is the seed of productivity growth, hence, resulting in translating high level of innovation engagement to sustainable real GDP growth (Gill & Kharas, 2007; Pece, Simona, & Salisteanu, 2015; Pradhan, Arvin, & Bahmani, 2018). The vital role of innovation as a growth engine and the importance of achieving an optimum level of innovation and R&D to economic growth has its origin from Schumpeter (1939), Romer (1986 and 1990), Grossman and Helpman (1991) and empirically supported by Aghion et al. (2005).

Using recent data, Lee and Kim (2009) revisited the debate and empirically found that factors such as technology, tertiary education and institutions are a significant determinant to economic growth. Interestingly, technology and higher education have been conclusively affecting economic growth for the upper-middle-income and high-income countries, but not for the lower-middle- and low-income countries. On the same account, an economy characterised with good quality education at both secondary and tertiary level and have a high-tech product share in export goods demonstrate resilience in economic growth to any slowdown effect (Eichengreen, Park, & Shin, 2013). This finding highlights the importance of moving up the technology ladder and indicates that innovation-enhancing growth strategies should receive priority.

Innovation management system and market protection for new ideas are other aspects to be considered to enhance further the role of innovation to economic growth. In this regard, Jalles (2010) found that countries with a higher degree of intellectual property rights (IPR), which reflects market protection for new ideas, generally have a higher level of income per capita. Wu, Zhuo and Wu (2017) found that the national innovation system (NIS) has significantly promoted social entrepreneurial action and enhanced economic growth in China's rural sectors. Hasan and Tucci (2010), on the other hand, stressed the importance of both the quantity (measured by total R&D expenditure) and quality of innovation (the ratio of patents granted in the United States as a proportion of total patents granted by the country) to economic growth. The study which analyses a sample of 58 countries covering 1980-2003 found that both the quantity and quality of inventive activities are associated with economic growth. The findings also demonstrate that those countries that have a high level of patenting, experience a concerted increase in economic growth.

With respect to the causality effect between innovation and economic growth, Galindo and Méndez (2014) analysed the feedback effects of a dynamic relationship among entrepreneurship, innovation and economic growth. They use entrepreneurial activity in 13 developed countries as a sample and the time period is from 2002 to 2007. Their empirical results based on panel data with fixed effects show that several factors, including monetary policy and social climate, have positive impacts on innovation and entrepreneurship. Furthermore, a bi-directional feedback effect is found from economic activity to entrepreneurship and innovation activities. This implies that there is a bi-directional feedback effect between innovation and economic activity.

In the case of high-income OECD countries, Guloglu and Tekin (2012) examined the causal relations among research and development (R&D) expenditures, innovation and economic growth using the panel vector autoregressive (VAR) model under the GMM and panel fixed effects framework. The study supports the endogenous growth theory where there is evidence of Granger causality from R&D expenditures to innovation, and technological innovations to economic growth. Interestingly, there is no evidence of reverse causality from economic growth to innovation; i.e. the rate of output growth Granger cause the technological change. The multivariate causality tests further confirm that both the market size and rate of innovation Granger cause R&D activity; while an increase in national output and R&D intensity jointly Granger-cause technological change. These empirical results depict that both the "technology-push" and "demand-pull" models of innovation are equally viable.

With regard to the roles of domestic innovation and foreign innovation in enhancing economic growth, Yang (2006) found that both domestic patenting and world discoveries of ideas are significantly driving the economic growth in Taiwan. The finding confirms that both domestic innovation and foreign innovation activities are equally important in promoting economic growth. Schneider (2005), on the other hand, found that foreign technology has a more substantial impact on per capita gross domestic product (GDP) growth than domestic technology. The empirical analysis is conducted using a panel dataset of 47 developed and developing countries. He argued that the roles of domestic innovation and foreign innovation are country-specific, where a time series analysis is more relevant in addressing this issue than a panel data analysis. Nevertheless, Cameron (1998) pointed out that positive technology spillovers tend to benefit multinational firms more while limiting local firms. The study suggests that although technological advancement across countries is converging to world productivity, the cathing up process is supposed to be slow, uncertain and require substantial domestic innovative effort.

Using 61 countries over the sample period from 2000 to 2011, Tan and Azman-Saini (2017) analysed the role of product market competition in accelerating the positive impact of foreign direct investment (FDI) on domestic research and development (R&D). The empirical results based on the panel generalized method of moments (GMM) demonstrate that FDI has a little direct effect on R&D expenditure. In other words, competition has a relatively moderate positive impact of FDI on domestic innovation. The finding is inconsistent with conventional wisdom regarding the merits of competition as evidence shows that competition undermines the effect of FDI on domestic innovation activities.

In short, innovation level is a critical determinant of economic growth.[2] Recently, the importance of innovation has been reinforced by both globalisation and advancement in information and communication technology which opened up new forms of competition and markets creation for innovative products and services. Nevertheless, a much more systematic approach that analyses the competition-growth nexus is still limited in the case of Malaysia. This study takes the first step in this direction.

3. Empirical Model, Methodology and the Data

To test the effect of innovation on economic growth, this study utilises the frameworks suggested by Mankiw, Romer and Weil (1992), Knight, Loayza and Villaneura (1993) and Law and Azman-Saini (2013). They applied the following Cobb–Douglas production function:

$$Y_t = K_t^{\alpha} \, H_t^{\beta} \, (P_t L_t)^{1-\alpha-\beta} \tag{1}$$

where Y is real GDP per capita, K is physical capital stock, H is human capital, L is labour, P is a labour-augmenting factor replicating the technological progress (innovation) and institutions effectiveness (institutional quality) in the economy and subscript t indicates time. Let's say $\alpha + \beta < 1$, this indicates that there are diminishing returns for all capital. Labour and labour-augmenting factor are assumed to progress based on the following functions:

$$L_t = L_0 e^{nt} \tag{2}$$

$$P_t = P_0 e^{gt+V\phi} \tag{3}$$

where n is exogenous rate of growth of the labour force, g is exogenous rate of technological progress, V is a vector of institutions and government policies that could move the technology and efficiency levels in the economy, and ϕ is a vector of coefficients associated with these institutions and government policies variables.

In this context, the state of labour-augmenting technology (variable P) is subject to exogenous technological change, determined by g and on a country's institutions and policy position namely corruption, law and order, bureaucratic quality, government stability, transparency and accountability. The technological change is stimulated by innovation such as on number of patents, number of grants, R&D, economic complexity and trade mark; and these innovations have a propensity for increasing the productive sector's efficiency or increasing the productivity of investment. In the steady state, output per active worker (Y/PL) is constant while output per worker (Y/L) rises at the exogenous rate g (the exogenous element of the growth rate of the efficiency variable P).

In reduced form, the output per worker can be reorganised as follows:

$$RGDPC_t = \beta_0 + \beta_1 \, INNO_t + \beta_2 \, INS_t + \beta_3 \, K_t + \beta_4 \, HC_t + \beta_5 \, PG_t + \varepsilon_t \tag{4}$$

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[2] Aghion et al. (2005) investigated the relationship between product market competition and innovation. Using panel data, they found strong evidence of an inverted-U relationship between these variables.

To evaluate the role of institutions in innovation, this study includes the interaction term between innovation and institutions as follows:

$$RGDPC_t = \beta_0 + \beta_1 \, INNO_t + \beta_2 \, INS_t + \beta_3 \, (INNO_t \times INS_t) + \beta_4 \, K_t + \beta_5 \, HC_t + \beta_6 \, PG_t + \varepsilon_t \quad (5)$$

where β is the parameter to be estimated, RGDPC is real GDP per capita, INNO is innovation, INS is institutions, K is physical capital, HC is human capital, PG is population growth, and ε_t is an error term. If β_1 is positive and significant, this demonstrates that innovation is an important determinant factor of economic performance. The remaining parameters namely β_2, β_3, β_4 and β_5 are also expected to be positive, which include the interaction term, institutions, physical capital and human capital, whereas the parameter of population growth (β_6) is projected to be negative.

3.1 Econometric Estimation Methods

i) ARDL Linear Bounds Test and Level Relations

The autoregressive distributed lagged (ARDL) model assumes that the linear bounds test leads to the conclusion of long-run cointegration and there is no non-linear relationship. Thus, we can expressively estimate the long-run level relationship between the variables based on Pesaran et al. (2001) uniform lag length (p, p, p, p, p, p) as follows:

$$RGDPC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \, RGDPC_{t-i} + \sum_{j=0}^{p} \gamma_j \Delta \, INNO_{t-j} + \sum_{k=0}^{p} \delta_k \Delta \, INS_{t-k} + \sum_{l=0}^{p} \lambda_l \Delta \, K_{t-l} +$$

$$\sum_{m=0}^{p} \varphi_m \Delta \, HC_{t-m} + \sum_{n=0}^{p} \eta_n \Delta \, PG_{t-n} + \theta_0 \, RGDPC_{t-1} + \theta_1 \, INNO_{t-1} + \theta_2 \, INS_{t-1} +$$

$$\theta_3 \, K_{t-1} + \theta_4 \, HC_{t-1} + \theta_5 \, PG_{t-1} + e_t \quad (6)$$

The same lag length is contingent on serial correlation or autocorrelation test (if there is a serial correlation problem, then the general to specific (GTS) procedure is employed to obtain different lag length (p, q, r, s, t, u). For example, if ARDL(1,1,1,1,1,1) is the optimal lagged model, then Equation (6) is as follows:

$$RGDPC_t = \mu_i + \beta \, RGDPC_{t-1} + \delta_1 \, INNO_t + \delta_2 \, INNO_{t-1} + \delta_3 \, INS_t + \delta_4 \, INS_{t-1} +$$

$$\delta_5 \, K_t + \delta_5 \, K_{t-1} + \delta_6 \, HC_t + \delta_7 \, HC_{t-1} + \delta_8 \, PG_t + \delta_9 \, PG_{t-1} + \varepsilon_t \quad (7)$$

and the short-run error-correction model (ECM) equation is represented as follows:

$$\Delta RGDPC_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta RGDPC_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta \, INNO_{t-j} + \sum_{k=0}^{r} \delta_k \Delta \, INS_{t-k} + \sum_{m=0}^{s} \eta_m \Delta \, K_{t-m} +$$

$$\sum_{n=0}^{v} \theta_n \Delta \, HC_{t-n} + \sum_{o=1}^{w} \tau_o \Delta PG_{t-o} + \phi Z_{t-1} + e_t \quad (8)$$

where $z_{t-1} = (RGDPC_{t-1} - \alpha_0 - \alpha_1 INNO_{t-1} - \alpha_2 INS_{t-1} - \alpha_3 K_{t-1} - \alpha_4 HC_{t-1} - \alpha_5 PG_{t-1})$ or the error correction term (ECT) and the αs are the ordinary least squares (OLS) estimates of the αs in Equation (8). The φ in Equation (8) is the short-run equation that contains the ECT that evaluates the quickness of adjustment of the short-run deviation to long-run equilibrium. p, q, r, s, v and w are the optimal lagged lengths, selected using the Schwarz Bayesian criterion (SBC).

Based on the above ARDL(1,1,1,1,1,1) model, we can compute the long-run coefficients of the determinants:[3]

$$\varphi_{INNO} = \frac{\gamma_1 + \gamma_2}{1 - \beta_i} \;;\; \varphi_{INS} = \frac{\delta_1 + \delta_2}{1 - \beta_i} \;;\; \varphi_K = \frac{\eta_1 + \eta_2}{1 - \beta_i} \;;\; \varphi_{HC} = \frac{\theta_1 + \theta_2}{1 - \beta_i} \;;\; \varphi_{PG} = \frac{\tau_1 + \tau_2}{1 - \beta_i} \;;$$

After getting the long-run equation, the error terms of the equation will be the error-correction term. The dependent variable for the short-run is changes (Δ) of RGDPC, and all the independent variables as well as in all changes. The short-run equation can be formulated as follows:

$$\Delta RGDPC_t = \alpha + \sum_{i=1}^{p-1} \alpha_i \Delta RGDPC_t + \sum_{j=0}^{q-1} \alpha_j \Delta INNO_t + \sum_{k=0}^{r-1} \alpha_k \Delta INS_t + \sum_{m=0}^{s-1} \alpha_m \Delta K_t +$$

$$\sum_{n=0}^{v-1} \alpha_n \Delta HC_t + \sum_{o=1}^{w-1} \alpha_o \Delta PG_t + ECT_{t-1} + e_t \tag{9}$$

ii) Quantile Regression

To evaluate for the nonlinearity in the relationship between the impact of innovation on economic performance, this study also uses a quantile regression to identify the effects under two dissimilar innovation indicators (Koenker, 2005; Koenker & Bassett, 1978). The purpose for selecting the nonlinear approach can be clarified by the spread of the innovation which is possible to capture using numerous quantiles. A quantile regression can disclose evidence on the unequal and non-linear results of the conditional variables on the dependent variable. In addition, it can detect the outcome of unforeseen changes in innovation on the signal and strength of economic performance across different quantiles. The regular linear regression procedures recap the average association between a set of independent variables (x) and the dependent variable (y) using the conditional mean function E(y|x). This offers merely a partial interpretation of the association, as this study analyses the association at dissimilar points in the conditional spreading of real GDP per capita, the quantile regression provides such capability in investigating the association between innovation and economic performance.

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[3] The long-run coefficients depend on the lag structure of the ARDL model; thus, different lags will yield different model specifications and derive different long-run elasticity equations.

3.2 Data

This study utilises yearly time series data spanning from 1985 to 2016 with 32 observations.[4] The sources of the data are from the *World Development Indicators* (WDI) and World Intellectual Property Organization (WIPO). The real gross domestic product (RGDP) per capita is obtained from the WDI in terms of US$ constant prices. Total patent applications and total number of grants are used as a measure of innovation following previous literature and these datasets are obtained from WIPO.

The physical capital stock is measured by using gross investment values based on the perpetual inventory method. Initial physical capital stocks are computed using the assumption that over long periods of time physical capital and output grow at the same rate. Following Hall and Jones (1999), a depreciation rate of 6% and the mean of economic growth rate of the initial 5 years are used to create the initial level of physical capital stock. Total population is used to measure the labour growth rate and human capital is proxied by life expectancy.

In this study, the institutions (INS) datasets utilised are from the International Country Risk Guide (ICRG) – which is a monthly publication of Political Risk Services (PRS). Based on Knack and Keefer's (1995) study, five PRS indicators are used to compute the institutions, specifically: (i) corruption, (ii) law and order, (iii) government stability, (iv) bureaucratic quality, and (v) democracy and accountability. The first three sub-institutions variables are scaled from 0 to 6, whereas the last two variables are scaled from 0 to 4 and 0 to 12, respectively. These five institutions variables are re-scaled from 0 to 10, where higher values indicate better institutions and vice versa. The aggregate institutions variable is obtained by summing the five sub-indicators above, which shows that the scale ranges from 0 to 50. Several studies have used this dataset in their work, among others, Bekaert, Harvey and Lundblad (2005, 2006), Chong and Calderón (2000), Demetriades and Law (2006), and Law and Azman-Saini (2012).

Tables 1 and 2 show the descriptive statistics and correlations of the variables. As shown in Table 2, the correlation demonstrates that real GDP per capita has a positive relationship with total patent application, total patent grants and institutions. Figure 2 presents the time series plots of the datasets used in the empirical analysis.

Table 1. Descriptive statistics

	Unit of measurement	Mean	Std dev	Min	Max
Real GDP per capita	Ringgit constant 2010 prices	7101.86	1998.88	3708.19	11031.82
Total patent application	% of 100000 labour force	4735.31	2011.52	262	7727
Total grants	% of 100000 labour force	2112.82	1646.06	132	6983
Population growth	Percent	2.86	0.36	1.70	3.54
Human capital	Number of years	72.64	1.60	69.48	75.30
Physical capital	% of GDP	27.96	7.42	20.57	43.58
Institutions	Scaled 0 – 50	29.95	2.91	25.14	36.32

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[4] The sample period stops at 2016 due to unavailability of data on institutions, total number of a patent application and total patent granted in the data sources.

Table 2. Correlations

	Real GDP per capita	Total patent application	Total grants	Population growth	Human capital	Physical capital	Institutions
Real GDP per capita	1						
Total patent application	0.8179	1					
Total grants	0.5981	0.1755	1				
Population growth	-0.9081	-0.5929	0.1755	1			
Human capital	0.9875	0.8326	0.8326	-0.8912	1		
Physical capital	-0.4764	-0.3289	-0.3289	0.4285	-0.5676	1	
Institutions	-0.0951	-0.0447	-0.0447	0.1158	-0.1637	0.5588	1

Total number of innovations   Real GDP per capita (US$)
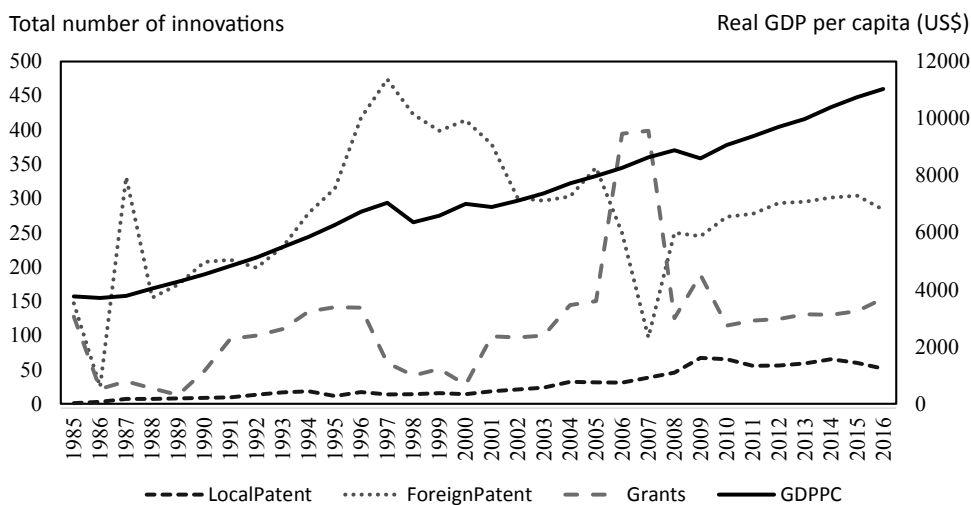
Figure 2. Innovations and real GDP per capita of Malaysia

4. Empirical Results

Table 3 presents the unit root tests based on the Augmented Dickey Fuller (ADF) and Philip Perron (PP) tests. The finding demonstrates that all variables are stationary at integrated order one or I(1). The result fulfils the ARDL bounds test criterion of no variable is integrated of order two or I(2).

Table 4 presents the empirical results of the linear ARDL estimation and diagnostic checks using the SBC lagged length selection criterion. The four models have passed the diagnostic checks especially the serial correlation and stability test. The main result is the long-run estimation reported in Table 5, where innovation proxy by total patent application is insignificant, but the total patent grants variable is statistically a significant determinant of economic performance. This finding reveals that quality innovation is

Table 3. ADF and PP unit root test

Variable	Level		First difference	
	ADF	PP	ADF	PP
Real GDP per capita	-1.1455	-1.1455	-4.9950***	-4.9879***
Total patent application	-1.7426	-1.5632	-7.1985***	-7.9034***
Total grants	-1.700	-1.5142	-7.268***	-7.3407***
Population growth	1.6180	-1.2475	-2.0805**	-2.0805**
Human capital	-1.8500	-3.4143**	-1.6645*	-3.5856***
Physical capital	-1.4408	-0.2781	-4.2274***	-4.1662***
Institutions	-1.0021	-0.9226	-3.8662***	-3.6629***
Foreign innovation	-3.0869**	0.9022	-12.3637***	-11.4801***
Local innovation	-4.2091***	1.6887	-5.3267***	-5.8524***

Notes: The constant and trend terms are included in the test equation and the SIC is utilised for optimal lag order in the ADF test equation. ***, ** and * denotes significance at 1%, 5% and 10% levels, respectively.

Table 4. Results of ARDL estimation and diagnostic checks

	Innovation = Total patent application		Innovation = Total grants	
	Model A	Model B	Model C	Model D
Panel A: Coefficient estimates of linear ARDL				
Selected model	(3,1,0,1,1,1)	(1,0,0,0,0,0)	(4,1,0,0,1,0)	(1,1,0,0,0,0,1)
Constant	-41.23***	-47.62***	-29.38***	-48.49***
	(10.96)	(9.82)	(8.45)	(7.65)
ln Real GDP per capita$_{t-1}$	-0.64***	-0.79***	-0.63***	-0.86***
	(0.18)	(0.15)	(0.15)	(0.13)
ln Innovation$_{t-1}$	-0.06**	-0.01	0.03**	0.02**
	(0.02)	(0.01)	(0.01)	(0.01)
ln Population growth$_{t-1}$	0.10	0.06	-0.001	0.09*
	(0.06)	(0.06)	(0.05)	(0.04)
ln Human capital$_{t-1}$	10.76***	12.55***	7.89***	12.89***
	(2.86)	(2.55)	(2.22)	(2.00)
ln Physical capital$_{t-1}$	0.17***	0.10***	0.10***	0.09***
	(0.04)	(0.02)	(0.03)	(0.02)
ln Institutions$_{t-1}$	0.22***	0.14*	0.18**	0.10
	(0.08)	(0.08)	(0.08)	(0.07)
ln Innovation$_{t-1}$ x ln Institutions$_{t-1}$		0.001*		0.002***
		(0.001)		(0.001)

Table 4. Continued

	Innovation = Total patent application		Innovation = Total grants	
	Model A	Model B	Model C	Model D
Δln Real GDP per capita$_{t-1}$	-0.31* (0.15)		-0.33** (0.14)	
Δln Real GDP per capita$_{t-2}$	-0.25* (0.13)		-0.32** (0.14)	
Δln Real GDP per capita$_{t-3}$			-0.25 (0.14)	
Δln Innovation$_t$	-0.01*** (0.02)	-0.01 (0.01)	-0.001 (0.01)	-0.005 (0.007)
Δln Population growth$_t$	0.10 (0.06)	0.06 (0.06)	-0.001 (0.05)	0.09* (0.04)
Δln Human capital$_t$	-28.77** (10.84)	12.55*** (2.55)	7.89*** (2.22)	12.89*** (2.00)
Δln Physical capital$_t$	0.25*** (0.04)	0.10*** (0.02)	0.17*** (0.04)	0.09*** (0.02)
Δln Institutions$_t$	0.07 (0.08)	0.14* (0.08)	0.18** (0.08)	0.10 (0.07)
Δln Innovation$_t$ x Δln Institutions$_t$		0.001* (0.001)		0.001 (0.001)
Panel B: Diagnostic results				
ECT$_{t-1}$	-0.64*** (0.08)	-0.79*** (0.07)	-0.63*** (0.07)	-0.86*** (0.05)
F-statatistic	7.37 ***	12.86 ***	8.08 ***	31.06***
Adjusted R^2	0.997	0.994	0.996	0.997
LM(2)	2.34	3.29	1.01	0.69
RESET test	0.92	3.22*	0.14	0.22
CUSUM (CUSUM^2)	S(S)	S(S)	S(S)	S(S)

F-test bounds critical value for n=30, k=5, Case 2 (for k=6)

	10%	5%	1%
Lower bound	2.407 (2.334)	2.910 (2.794)	4.134 (3.976)
Upper bound	3.517 (3.515)	4.193 (4.148)	5.761 (5.691)

Notes: ***, ** and * indicate 1%, 5% and 10% significant levels, respectively. The number in parentheses show the standard error for the respective coefficient. LM is the Breusch-Godfrey serial correlation test with the number of lags as stated in parentheses. RESET test is the Ramsey's reset test for misspecification of model. For CUSUM and CUSUM^2, S stands for stable. The models are estimated with trend if only it is significant at 10% level. F-test lower and upper bound critical values are from Narayan (2005).

Table 5. Long-run results (linear ARDL model)

	Innovation = Total patent application		Innovation = Total grants	
	Model A	Model B	Model C	Model D
ln Innovation	-0.09 (0.04)	-0.01 (0.02)	0.05** (0.02)	0.02** (0.01)
ln Population growth	0.15 (0.09)	0.08 (0.08)	-0.001 (0.08)	0.10** (0.04)
ln Human capital	16.70*** (1.29)	15.86*** (0.91)	12.61*** (0.93)	14.93*** (0.46)
ln Physical capital	0.26*** (0.08)	0.13*** (0.03)	0.16*** (0.05)	0.10*** (0.02)
ln Institutions	0.35*** (0.09)	0.18** (0.08)	0.29** (0.12)	0.12* (0.07)
ln Innovation x ln Institutions		0.002* (0.001)		0.003*** (0.001)

Notes: ***, ** and * indicates 1%, 5% and 10% significant levels, respectively. The number in parentheses shows the standard error for the respective coefficient.

more crucial than quantity innovation. The result of the study that finds a negligible contribution of innovation in Malaysia is of no surprise. It is because over the past years Malaysia has experienced a very low successful rate for both intellectual property commercialisation (Govindaraju & Wong, 2011; Govindaraju, Abdol Ghapar, & Pandiyan, 2008; 2009) and commercialisation of public R&D. Asid and Khalifah (2016) supported this finding whereby they found that the initial triadic pattern only marginally improves technical efficiency. It seems that there is a "disconnect" paradox between innovation and commercialisation programs in Malaysia.

The other control variables such as physical capital stock, human capital and institutions are statistically significant determinants of economic performance in Malaysia, which is in line with the theory. For example, Baharumshah and Almasaied (2009) and Lai and Ishhak (2014) found that human capital is important for promoting Malaysian economic performance. Ang (2008), Ayub, Azman-Saini, Laila, Mongid and Wan Ismail (2019), Solarin and Shahbaz (2015) and Tang and Tan (2015) demonstrated that physical capital or investment is positively associated with economic performance in Malaysia. With respect to institutions, Bekhet and Abdul Latif (2018), Mo (2019) and Sarmidi, Law and Jafari (2014) revealed that the institutions variable is vital in promoting economic performance in Malaysia. In terms of the interaction between innovation and institutions, the finding shows that only the total patent grants variable is significant, whereas the total patent application is insignificant.

Table 6 presents the empirical results of the linear ARDL estimation and diagnostic checks for the relative importance of local and foreign innovation, which is only available for total patent application. The three models have passed the diagnostic checks especially the serial correlation and stability test. The main result is the long-

Table 6. Linear ARDL estimation results and diagnostic checks

Variable	Model A	Model B	Model C
Panel A: Coefficient estimates of linear ARDL			
Selected model	(3, 1, 0, 1, 1, 1)	(1, 0, 0, 0, 0, 0)	(3, 1, 0, 0, 1, 1, 1)
Constant	-40.40 (10.73)***	-39.20 (11.28)***	-43.12 (12.17)***
ln Real GDP per capita$_{t-1}$	-0.65 (0.17)***	-0.72 (0.16)***	-0.66 (0.18)***
ln Foreign innovation$_{t-1}$	-0.05 (0.02)***		-0.05 (0.02)**
ln Local innovation$_{t-1}$		0.01 (0.02)	-0.01 (0.02)
ln Population growth$_{t-1}$	0.09 (0.06)	0.05 (0.06)	0.10 (0.06)
ln Human capital$_{t-1}$	10.58 (2.80)***	10.41 (2.90)***	11.23 (3.14)***
ln Physical capital$_{t-1}$	0.17 (0.04)***	0.10 (0.02)***	0.17 (0.04)***
ln Institutions$_{t-1}$	0.21 (0.07)**	0.15 (0.08)*	0.23 (0.08)**
Δln Real GDP per capita$_{t-1}$	-0.31 (0.14)**		-0.30 (0.15)*
Δln Real GDP per capita$_{t-2}$	-0.25 (0.12)*		-0.23 (0.13)*
Δln Foreign innovation$_t$	-0.01 (0.02)		-0.01 (0.02)
Δln Local innovation$_t$		0.01 (0.02)	-0.01 (0.02)
Δln Population growth$_t$	0.09 (0.06)	0.05 (0.06)	0.10 (0.06)
Δln Human capital$_t$	-31.71 (11.06)**	10.41 (2.90)***	-28.93 (12.53)**
Δln Physical capital$_t$	0.25 (0.04)***	0.10 (0.02)***	0.25 (0.04)***
Δln Institutions$_t$	0.06 (0.08)	0.15 (0.08)*	0.08 (0.09)
Panel B: Diagnostic results			
ECT$_{t-1}$	-0.65 (0.08)***	-0.72 (0.07)***	-0.66 (0.08)***
F-statistic	7.66***	13.40***	6.43***
Adjusted R^2	0.997	0.994	0.997
LM(2)	2.15	1.63	3.87
RESET test	1.01	3.88*	0.75
CUSUM (CUSUM^2)	S(S)	S(S)	S(S)

F-test bounds critical value for n=30, k=5, Case 2 (for k=6)

	10%	5%	1%
Lower bound	2.407 (2.334)	2.91 (2.794)	4.134 (3.976)
Upper bound	3.517 (3.515)	4.193 (4.148)	5.761 (5.691)

Notes: ***, ** and * indicate 1%, 5% and 10% significant levels, respectively. The number in parentheses shows the standard error for the respective coefficient. LM is the Breusch-Godfrey serial correlation test with the number of lags as stated in parentheses. RESET test is the Ramsey's reset test for misspecification of model. For CUSUM and CUSUM^2, S stands for stable. The models are estimated with trend if only it is significant at 10% level. F-test lower and upper bound critical values are from Narayan (2005).

Table 7. Long-run results (linear ARDL model) of relative importance of local and foreign innovations

Variable	Model A	Model B	Model C
ln Foreign innovation	0.078 (0.03)**	–	0.072 (0.04)**
ln Local innovation	–	0.023 (0.03)	-0.021 (0.03)
ln Population growth	0.14 (0.08)	0.07 (0.07)	0.15 (0.08)*
ln Human capital	16.16 (1.01)***	14.42 (1.37)***	17.04 (2.01)***
ln Physical capital	0.26 (0.08)***	0.14 (0.04)***	0.25 (0.08)***
ln Institutions	0.33 (0.08)***	0.20 (0.09)**	0.35 (0.10)***

Notes: ***, ** and * indicate 1%, 5% and 10% significant levels, respectively. The number in parentheses shows the standard error for the respective coefficient.

run estimation reported in Table 7 which reveals that foreign innovation is a significant determinant of economic performance, whereas local innovation is insignificant. Again, our inclusion of both variables in the same model specification indicate that foreign innovation is significant, but not the local innovation.

Table 8 reports the quantile regression results and the finding shows that the effect of innovation (total patent grants) differs considerably, having a strong effect on economic performance at lower quantiles (10 percentile and 25 percentile). This empirical result demonstrates that the effect is much stronger at lower quantiles. Figure 3 presents the coefficient distributions of each variable; the total patent grants variable is diminishing the coefficients which is in line with the lower quantiles whereby the coefficients are significant. This result demonstrates that our innovation variable is not statistically significant as compared to literature in other developed countries (Ang, 2010; Laincz & Peretto, 2006). The institutions variable reveal that higher quantiles level of the coefficients have higher values which are consistent with the literature, where better institutions promote economic performance. The human capital variable also reveals the same pattern.

5. Conclusion

Motivated by differences in innovation intensity across countries, this paper analyses an empirical investigation of the role of innovation in economic performance in Malaysia. Using the autoregressive distributed lag (ARDL) bounds test procedure, this study utilises an output per labour framework based on the notion of economic performance capacity. The time series data is from 1985 to 2016. The empirical results indicate that total patents granted that measures the quality of innovation is a statistically significant determinant of economic performance, which implies that quality innovation is more vital compared to quantity innovation. In terms of local and foreign innovations, the foreign innovation has a greater impact on economic performance. With respect to the roles of institutions in the innovation–economic growth nexus, the result reveals that institutions are crucial in accelerating the effect of innovation on economic performance.

Table 8. Results of quantile regression

Real GDP per capita	Coefficient	Bootstrap standard error	t-stat	p-value
Q10				
Total grants	0.0002	9.41E-05	2.03*	0.053
Institutions	0.0050	0.0041	1.22	0.233
Population growth	0.0362	0.1165	0.31	0.759
Human capital	14.731	0.7266	20.27***	0.000
Physical capital	0.0984	0.0318	3.09***	0.005
Constant	-54.866	-3.3299	16.48***	0.000
Q25				
Total grants	0.0002	9.71E-05	2.07**	0.049
Institutions	0.0038	0.0035	1.08	0.290
Population growth	0.0352	0.1219	0.29	0.775
Human capital	14.6149	0.7901	18.5***	0.000
Physical capital	0.1167	0.0388	3.00***	0.006
Constant	-54.389	-3.6071	15.08***	0.000
Q50				
Total grants	0.0002	0.0001	1.67	0.107
Institutions	0.0074	0.0024	3.03***	0.005
Population growth	0.1722	0.0893	1.93*	0.065
Human capital	15.547	0.5361	29.00***	0.000
Physical capital	0.1253	0.0219	5.71***	0.000
Constant	-58.645	-2.4318	24.12***	0.000
Q75				
Total grants	0.0001	0.0001	1.29	0.210
Institutions	0.0078	0.0028	2.78***	0.010
Population growth	0.0919	0.0984	0.93	0.359
Human capital	15.018	0.5534	27.13***	0.000
Physical capital	0.1430	0.0314	4.55***	0.000
Constant	-56.346	-2.4678	22.83***	0.000
Q90				
Total grants	0.0001	0.0002	0.47	0.641
Institutions	0.0097	0.0046	2.1**	0.046
Population growth	0.1327	0.1473	0.9	0.376
Human capital	15.471	0.8063	19.19***	0.000
Physical capital	0.1075	0.0535	2.01*	0.055
Constant	-58.252	-3.5521	16.4***	0.000

Note: ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.
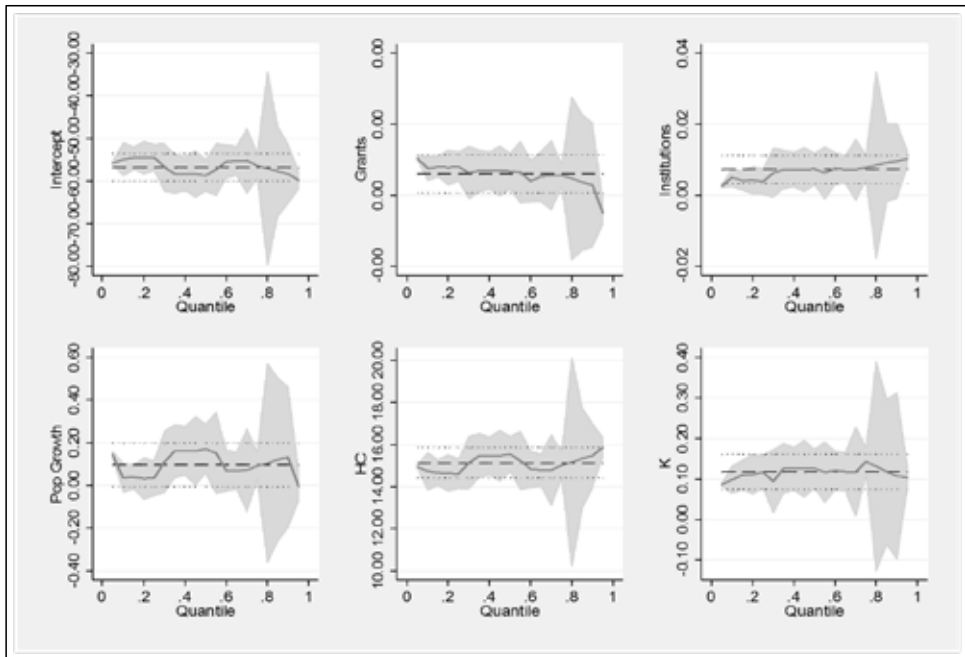
Figure 3. Quantile regression graph (the graphs show the estimates of the slope coefficients in the x-axis against the quantiles of economic performance in the y-axis)

In industry 4.0 era, technological advancement and digitisation are two important pillars for a competitive economy. Malaysia has to strategically ensure that the innovation of new technologies is adequate to drive a sustainable and inclusive economy. To achieve these aims, first, our study suggests the imperative of having new stock of novel ideas. We are producing a shallow level of innovation as compared to other countries. Second, the quality of innovation should be of prime importance. A number of new ideas alone may not significantly impact the economic performance.

The current study shows that inadequacy of innovative technology flow over the long term has a detrimental effect on innovative capacity. Premium institutional quality is of utmost priority and urgency. Our study confirms that institutional quality acceler-ates the innovation impact on economic performance. Any move that could shape better institutional quality including improvement of human capital, reduction in the digital literacy gap, innovation tax incentive, and higher quality of networking are vital.

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