

Analysis of the causal effects of imports and foreign direct investments on indigenous innovation in developing countries

Foreign trade
and indigenous
innovation

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Abstract

Purpose – The purpose of this study is to analyze the performance of indigenous innovation in developing countries in the era of trade liberalization. It analyzes indigenous innovation from research and development (R&D) investments to innovation output and its effect on economic growth.

Design/methodology/approach – The sample for this study includes 20 middle-income countries across five continents for the period between 1994 and 2018. The study employs the Crepon Duguet and Mairessec CDM model in a panel data setting to do a multistage analysis of the innovation process. A vector error correction model VECM is employed to test for Granger causality between the variables investigated.

Findings – The results show that imports and foreign direct investments (FDI) have generally have short-run and long-run causal effects on domestic R&D investments. In regions where imports and FDI do not have individual causal effects on innovation output, a joint increase in each of them and R&D have both short-run and long-run causal effects. Indigenous innovation is a significant contributor to economic growth when a country can produce and export novel products.

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Research limitations/implications – The sample is only limited to developing economies, and due to the unavailability of data, only 20 countries were captured.

Practical implications – Imported products and FDI are critical to the innovation drive when such activities are targeted at enhancing indigenous innovation from R&D to the production of new products. Hence, policy formulation should encourage the absorption of foreign technologies that serve as inputs to indigenous innovation.

Originality/value – This paper focuses specifically on indigenous innovation and analyses the influence of foreign technologies in this effort. It tests the moderating roles of imports and FDI in the relationship between R&D and innovation output, concluding that both variables enhance the effect of R&D on innovation output.

Keywords Indigenous innovation, Trade liberalization, Economic growth, Developing countries

Paper type Research paper

1. Introduction

Endogenous economic growth depends on several factors including technological innovation. Schumpeter (1934) posited that technological innovation plays a critical role in the development of a nation. This form of economic activity ensures that a country produces new technologies through local businesses which are the main drivers of economic growth. Indeed several researchers have extensively studied the role that innovation plays in economic development (Pece *et al.*, 2015; Hu, 2015; Broughel and Thierer, 2019). Most of these scholars found a positive and significant effect of innovation on economic growth. The economic growth of a society is largely accounted for by the extent to which that society engages in innovation activities, because low levels of innovation activity hinder economic growth (Awdeh and Hamadi, 2019). While agreeing with this notion, some scholars have established a unidirectional causality between the two variables. They argue that economic growth is mainly influenced by innovation and not the vice versa. Other researchers have established a bidirectional causality between these two variables (Howells, 2005; Pradhan *et al.*, 2016). Hence, one of the major strategies for developing countries to grow and catch up with the developed world is through innovation at the micro and macro levels.

Furthermore, as Goedhuys (2007) indicated, business organizations should be leading the innovation drive in developing countries. However, these businesses still grapple with challenges such as access to finance, lack of expertise and general technology deficiency, while at the same time facing competition from imported products. Debrah *et al.* (2018) pointed out poor infrastructure and unfavorable government policies as some of the challenges facing medium-sized enterprises that play a major role in developing economies. Much of extant literature on how indigenous innovation influences economic growth is documented on developed and transition economies. The few studies on developing economies have largely tested the relationship between innovation in general and economic growth. Moreover, not much is seen in the extant literature on how trade liberalization has impacted indigenous innovation and its effect on the growth of developing countries. This study extends these works by assessing how indigenous innovation influences economic growth in developing economies. The study further assesses moderating role of foreign technologies in the relationship between research and development (R&D) and indigenous innovation output.

Trade liberalization aims to achieve a seemingly borderless trade among nations, opening up domestic markets to trade partners, and getting access to international markets as well. Trade liberalization encourages FDI and the import of technologies that affect domestic innovation (Tee *et al.*, 2018). Achieving endogenous growth through indigenous innovation under a liberalized economy can be challenging, considering the import of products from technologically advanced economies (Seenaiah and Rath, 2018). Access to international markets also presents opportunities for local businesses to learn, adapt and innovate new

technologies (Di Cintio *et al.*, 2020). Developing countries in their quest for endogenous economic growth through innovation are still caught up in the “catching-up” agenda. Countries in this dilemma must either escape through a window of opportunity or remain caught up in trying to catch up. The question therefore remains; after long periods of trade liberalization, is economic growth through indigenous innovation improving or worsening? An attempt to find answers to this question and contribute to the literature on this subject propelled the current study.

This study therefore, adds to the existing literature on innovation and economic growth by making the following contributions. (1) The study adopts a multistage approach using the Crepon *et al.* (1998) (CDM) model to test innovation performance at the country level as against the firm-level analysis it is noted for. (2) The effect of trade liberalization on indigenous innovation is examined by assessing the roles of imports and foreign direct investments (FDI) in R&D intensity and innovation output in developing countries. (3) The CDM model is extended to include the moderating roles of imports and FDI in the innovation process, and the impact of the export of new products on economic growth.

The study is subsequently organized as follows: Section 2 contains a review of literature. Section 3 follows with an explanation of the methodology and econometric model used in the study. Section 4 deals with analysis and discussion of results, whilst Section 5 presents conclusions and policy ideas.

2. Related literature

2.1 Indigenous innovation

The concept of indigenous innovation was first created by the government of China in 2006 in a quest to promote innovation among local businesses. This campaign was called the “National Medium and Long Term Program for Scientific and Technological Development”, and was aimed at positioning China as a technology hub by 2020, and a global leader of innovation by 2050. The campaign encompassed a comprehensive regulatory regime to reduce the reliance on imported technologies and develop more indigenous technologies to aid the development process (Chow, 2013). This strategy has been widely adopted by other countries in a bid to ensure endogenous growth through technologies developed by domestic firms. China planned to achieve this by investing at least 2.5% of gross domestic product (GDP) annually in a bid to transit from catching up to leadership in innovation (Vinig and Bossink, 2015). The indigenous innovation drive is working effectively for China as the country has been making strides as an innovation hub of the world. Indeed, the Global Innovation Index (2019) reports that China leads the few middle-income countries that are breaking the ceiling into the level of innovation that was hitherto a preserve of high-income countries.

An indigenous innovation strategy seeks to achieve three main things: develop new technologies, combine existing technologies in different ways, and making improvements on imported technologies. A strategy of this nature encourages innovation among domestic businesses as it is backed by regulations that ensure access to resources (Akinwale, 2018). Akinwale (2018) argues that the assimilation of foreign technologies remains a challenge for developing countries as there is a low capacity to diffuse imported technologies. Fu *et al.* (2011) posited that local businesses can benefit from foreign technologies if there are comparative indigenous innovation efforts. Indigenous knowledge and building local capacity are the bases of indigenous innovation, hence, the two concepts cannot be delinked (Nakata, 2002). Xie *et al.* (2015) opined that external knowledge is essential to the growth of indigenous innovation, supporting the idea that foreign technologies and knowledge are critical to the development of novel technologies in the local market. These arguments enforce

the fact that in building local capacity for indigenous innovation, external knowledge still plays a critical part in the process.

Trade openness has encouraged the transfer of knowledge (Akinwale and Grobler, 2019) which has been seen as fundamental to economic growth (Adelowo *et al.*, 2017). The economic survival and growth of a nation are largely dependent on the technical know-how of a country to turn resources into novel products and technologies. Akinwale *et al.* (2012) argued that the global economy is largely dominated by technologically advanced countries that are investing heavily in R&D and applying science and technology to generate indigenous knowledge leading to the development of new technologies. Indigenous innovation can benefit developing economies in several aspects including education, agriculture, health care, arts and crafts, employment, and a host of other economic activities.

2.2 Trade liberalization and innovation

Trade liberalization encourages imports, exports and foreign direct investments (FDI) inflows. Paul and Jadhav (2019) found that institutional quality, infrastructure and political stability are among factors that determine FDI inflows in developing economies. Foreign investors bring into the host market new technologies and technical knowhow that are typically new to the local economy. The import of foreign goods including new technologies has been strongly linked to innovation growth in developing economies. Extant literature shows that imports into developing countries create “escape-competition” that propels creativity and innovation among domestic firms (Xie and Li, 2018; Seenaiah and Rath, 2018; Shu and Steinwender, 2019). Studies have shown that in the aftermath of trade liberalization, innovation efforts have been on the increase with foreign goods flooding local markets (Fernandes and Paunov, 2013). Competition from imported products appears to have spurred innovation more in large firms (Fernandes and Paunov, 2013) and technologically advanced firms as opposed to small enterprises that constitute a large part of businesses in developing economies (Iacovone, 2012). Medina (2017) argued that import competition could bring about product upgrading opportunities, and local firms will react to changing preferences by leveraging existing factors to produce new products (Bloom *et al.*, 2016). Yet again, another argument advanced by many authors for the positive effect of imports on innovation is the idea of access to intermediate goods that serve as inputs to new product designs. These inputs become more available as more foreign firms find grounds for such, thereby reducing costs associated with novel technologies that aid the innovation process (Fieler *et al.*, 2018).

Additionally, imported inputs have been linked to increased productivity among firms in the receiving market (Okafor *et al.*, 2017). Though some studies have found that imported products have mixed effects on innovation, products that are imported as inputs generally have positive effects on innovation in the domestic market (Xie and Li, 2018; Shu and Steinwender, 2019). Bas (2012) had earlier argued that importing products as inputs to the innovation process, known as direct imports, had a positive and significant effect on innovation at firm level, a view affirmed by Okafor *et al.* (2017). The import of such inputs has the tendency to spur innovation among local firms that are competing to supply inputs to local producers. The quest to compete favorably with imported product can raise the productivity of businesses in developing countries, which will lower production costs and allow them access to international markets (Feng *et al.*, 2016).

Furthermore, a major economic activity that comes with trade liberalization is FDI (Kumari and Sharma, 2017) and most developing countries benefit from technology transfer that comes with FDI. Kastrati *et al.* (2016) are among several scholars who argued strongly for the positive effect of FDI on local innovation. Cheung and Ping (2004) posited that countries benefit from FDI in their innovation efforts in the following ways; first, domestic firms can adapt and improve upon new product ideas from their foreign counterparts, hence coming up with their innovations. Second, people who have worked for foreign firms can pass that

knowledge to domestic firms when they leave the former and join the latter. Third, the presence of foreign products can stimulate domestic firms to be creative and therefore churn out new product ideas. [Cassiman and Veugelers \(2002\)](#) opined that successful innovation is largely dependent on the integration of new knowledge, such knowledge can come from FDI as foreign firms seize opportunities that are yet to be exploited in developing economies. On the back of this, developing countries stand to gain from this form of knowledge transfer to improve upon innovation in local firms to enable them compete in international markets ([Villar et al., 2019](#)).

At the center of the innovation drive is R&D which is well acclaimed to be a key input in the process. Several scholars have found a positive effect of R&D on the generation of new knowledge ([Teplykh, 2016](#); [Li et al., 2019](#)). For a country to get any benefits from knowledge spillover and boost its R&D efforts, the absorptive capacity of such a country needs to be developed. Absorptive capacity is associated with the level of skills of the workforce of a country. Skilled workforce has been noted to be an important factor for innovation. Taking up technologies from foreign countries is a major contribution to product innovation in many firms. Though absorptive capacity is distinct from innovation itself, it nevertheless is an important prerequisite for successful innovation ([Reid, 2019](#)). Aside from the role it plays as an input to innovation, R&D also serves as a platform for the diffusion and use of knowledge from foreign sources ([Pierre and Bronwyn, 2013](#)).

2.3 Innovation-economic growth relationship

Economic growth is described as a country's ability to increase its production of goods and services year on year ([Lewis, 2013](#)). In this study, gross domestic product (GDP) is used as a measure of economic growth. Even though the use of GDP to measure economic growth is largely criticized for its inability to capture the true livelihood of the populace ([Broughel and Thierer, 2019](#)), it remains the most popular tool used by economists for this purpose. Endogenous growth theory posits that economic growth is largely influenced by human capital and technological innovation. This theory argues that growth comes as a result of the internal processes of a system. As businesses grow, the economy expands through employment, tax revenues, foreign exchange through exports, etc. [Metcalf and Ramlogan \(2008\)](#) stated that effective economic growth is ultimately linked to a country's ability to acquire and use new technologies. This capacity can be enhanced by developing an innovation culture embodied in a country's National Innovation System (NIS).

Besides, the literature on this subject largely concurs that countries can benefit from innovation in a quest for economic growth. Though some critics have down-played the role of innovation in national development, it undeniably remains a significant contributor to economic growth ([Broughel and Thierer, 2019](#)). [Hu \(2015\)](#) pointed out that countries that are not technologically advanced can achieve economic growth through innovation by adopting technologies from other countries. [Romer \(2000\)](#) stressed that endogenous growth can be propelled by the generation of new knowledge by increasing R&D investments. The generation of such new knowledge leads to innovation in various aspects of the economy which will, in turn, lead to growth in the entire economy ([Dosi and Nelson, 2010](#)).

Moreover, some economists have concurred that capital formation, which is a critical factor for economic growth, contributes about 30% to this growth ([Jones and Romer, 2010](#)), the remaining 70% can be attributed to the discovery and use of technologies that enable a country to bring out more innovations ([Lipsey et al., 2005](#)). [Acemoglu and Robinson \(2012\)](#) stated that sustained economic growth is achieved through innovation. Such innovation activities are known to be driven by the discovery and use of technologies usually known as general-purpose technologies (GPT) ([Gordon, 2000](#)). GPTs are learned and adopted by importing or learning from foreign investors.

Exporting to other countries is noted to be a major boost for innovation. To seize opportunities that exist elsewhere, businesses need to design products that can satisfy such needs, hence the need for novel ideas. The argument advanced for this concept is that firms learn by exporting to other countries due to new challenges and opportunities (Autor *et al.*, 2016; Bombardini *et al.*, 2017). Ahn *et al.* (2018) argued that technologically advanced firms usually respond to export opportunities by innovating to meet the expectations of the international target market, a view that is largely referred to as “learning-by-exporting”. Atkin *et al.* (2017) reported that developing countries are benefiting from this learning when they export to more developed economies where there are scope and opportunities for marketing more products.

As evidenced in the above literature, a lot of work has been done on the innovation-economic growth nexus. This study seeks to add to the literature by examining how imports and FDI influence the domestic R&D process. Since this is a multi-stage analysis, it expands the scope of the analysis to cover a variety of issues in this subject area.

3. Materials and methods

To achieve the objective of this study, we employ the Crepon *et al.* (1998) (CDM) model to analyze how trade liberalization influences indigenous innovation in developing countries and to further analyze how indigenous innovation contributes to the economic growth of these countries. To analyze this model effectively, we first analyze the stationarity of the data using the Pesaran (2007) CIPS test for unit root which takes into account cross-sectional dependence in the data. Further, we test for cointegration among variables under study, and finally, a panel vector error correction model (VECM) is estimated to analyze the short-run and long-run causal relationships between the variables. The variables for this study are described in Appendix 1.

3.1 Data

Data for this study is taken from the World Development Indicators (WDI) by the World Bank Group (www.data.worldbank.org/indicator). The data covers twenty countries across the continents of Africa, Asia, Europe, North America, and South America for the period between 1994 and 2018. The countries were chosen based on economic status and data availability. The sample involves developing countries from five regions. These include Africa (Egypt, Morocco, Algeria and Tunisia), Asia (Thailand, Pakistan, Philippines and Sri Lanka), Europe (Bulgaria, Belarus, Ukraine and Moldova), North America (Costa Rica, Mexico, Panama and Haiti) and South America (Argentina, Columbia, Ecuador and Peru).

3.2 Unit root analysis

We check for stationarity of the data by conducting a unit root analysis. For a study of this nature with heterogeneous panels, it is appropriate to adopt a method of test that accounts for cross-sectional dependence in the data. Therefore we use the cross-sectionally augmented IPS (CIPS) by Pesaran (2007) to test for stationarity of the data. This test filters out the cross-sectional dependence in the series (Cavalcanti *et al.*, 2011). The CIPS test is based on the following equation:

$$\Delta y_{it} = \alpha_i + b_i y_{it-1} + \gamma_i f_i + \varepsilon_{it} \quad (1)$$
$$i = 1, 2, \dots, N. \quad t = 1, 2, \dots, T$$

where $\Delta y_{it} = y_{it} - y_{it-1}$; y_{it} is an i th item observed at time t , α_i is the intercept, and b_i is the parameter of y_{it-1} . $\gamma_i f_i$ represents the cross-sectional dependence element where γ_i is a factor

that is common to all cross-sectional units i , and f_i is the latent factor, while ε_{it} is the error term. Negative values for b_i are to be expected where there is an absence of unit root. The test hypothesis is defined as:

$$H_0 : b_i = 0; \forall i = 1, 2, \dots, N$$

$$H_1 : b_i < 0; \forall i = 1, 2, \dots, N$$

The result of the stationarity test will show the nature of the relationship that exists between the variables tested. In the absence of unit root, it would mean that the effect of the independent variable on the dependent variable is transitory. In this case, the variables return to long-run equilibrium after a shock in the system. However, a non-stationary series would indicate that there is a permanent effect when there is a shock in the system. Nevertheless, when there is unit root and a subsequent cointegration between the variables, the effect of any shock would still be transitory. In this case, however, if there is no cointegration, any effect resulting from a shock in the system would be permanent.

3.3 Cointegration analysis

A cointegration test will establish a long term correlation between the variables under study. This test is conducted to determine the situation where time series variables are integrated such that there will be long term convergence after a shock occurs in the system. In this study we employ two methods to test for cointegration, first is the [Pedroni \(2004\)](#) test and second is the [Kao \(1999\)](#) test. The [Pedroni \(2004\)](#) test is advantageous due to its ability to allow for fixed effects and deterministic trends. It also accounts for group mean between dimension and pooled mean between dimension tests, while allowing for short and long term heterogeneity among individual variables. The test produces two results; the weighted statistics and the group statistics. The Kao cointegration test is also preferred due to its ability to correct for bias where variances are similar in all cross-sections. The test uses long-run covariance to remove any bias induced by serial correlation of the error term which can limit distribution within the system. These tests are based on the null hypothesis of no cointegration, and a rejection of the same means there is long-run cointegration between variables.

3.4 Econometric model

The CDM model is used in this study to assess the level of innovation activities, innovation output, and its effect on the growth of developing economies. The classical CDM model contains four stages, the first and second steps seek to describe the innovation efforts of an entity (intention to invest in R&D and actual investments in R&D). The third step analyses the level of output (innovation), and the fourth step describes the performance of the novel idea. One major problem in analyzing innovation performance is simultaneity which arises because entities differ in factors they consider important in their decision to innovate, their levels of expenditure, and the performance of new product ideas. The model is commonly used due to its ability to overcome some of these difficulties encountered in measuring innovation and productivity.

The general formulae for this model are written as follows:

The first stage ([Eqn \(2\)](#)) depicts the intention to undertake R&D; hence

$$g_i = \beta_0 x_{0i} + \varepsilon_{0i} \quad (2)$$

where g_i is the decision criterion, x_{0i} represents the explanatory variables; β_0 is the coefficient of explanatory variables, and ε_{0i} is the error term.

Eqn (3) representing the second stage is the actual intensity of R&D

$$k_i = \beta_1 x_{1i} + \varepsilon_{1i} \tag{3}$$

where k_i is the intensity of R&D; x_{1i} is explanatory variables; β_{1i} is the coefficient of explanatory variables, and ε_{1i} the error term. In principle, the explanatory variables (x_0 and x_1) are the same.

The third stage represents the innovation output

$$t_i = \beta_2 k_i + \beta_2 x_{2i} + \varepsilon_{2i} \tag{4}$$

where t_i is the innovation output, k_i and x_{2i} are the R&D and explanatory variables respectively, and ε_{2i} is the error term.

The fourth stage, performance equation, tests the level of success of the innovation output. The estimated performance equation is:

$$q_i = \beta_3 t_i + \beta_3 x_{3i} + \varepsilon_{3i} \tag{5}$$

where q_i is the performance variable, t_i is the innovation output variable, x_{3i} is explanatory variables.

3.5 The extended CDM model

Since Crépon *et al.* (1998) proposed the CDM model to analyze firm level data, several scholars have adapted and applied it in different contexts. This study employs the CDM model to analyze the relationship between indigenous innovation and economic growth at the country level. In our extended CDM model we consider how imports and FDI moderate the relationship between research and development (R&D) and innovation output, and the impact of indigenous innovation on the growth of developing economies.

3.5.1 R&D intensity. The explanatory variables for the first and second stages of the CDM model are essentially the same; therefore, we only construct an equation to study the function of R&D intensity for every country with R&D input (Masso and Vahter, 2014; Yuan and Xiang, 2018). The main idea is to estimate the effect of imports and FDI on R&D intensity among the countries under study. The variables of focus are imports and FDI, these are part of international trade arrangements that can have an important influence on R&D intensity. The independent variables are arranged in a decreasing order of exogeneity in order to get effective results in a vector autoregressive (VAR) system. We expect imports to react faster to R&D than FDI, hence, the panel VECM granger causality estimation of R&D intensity is estimated in model 1 as follows:

Model 1

$$\begin{bmatrix} \Delta R\&D_{it} \\ \Delta FDI_{it} \\ \Delta IMP_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} + \sum_{j=1}^p \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{12j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} \end{bmatrix} \begin{bmatrix} \Delta R\&D_{it-j} \\ \Delta FDI_{it-j} \\ \Delta IMP_{it-j} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} u_{1it} \\ u_{2it} \\ u_{3it} \end{bmatrix}$$

where Δ is the first difference, p is the lag length selected based on the Akaike and Hannan-Quinn information criteria, and u_{it} is the error term. The first difference operators of the variables represent the short-run causal relationship between variables, while long-run causality is represented by λ .

3.5.2 Innovation estimation. We consider innovation output as trademark applications by residents of each country. The effect of imports and FDI on innovation output is examined in model 2. In model 3 we estimate how imports and FDI moderate the relationship between R&D and innovation output. This is tested by generating interacting

variables between R&D and imports, and R&D and FDI. These interactions between variables will help to uncover how innovation output is affected by the complementarity between foreign technologies and local R&D. Ordering variables in a decreasing order of exogeneity, we measure their effect on innovation output via the VECM granger causality in models 2 and 3 as follows:

Model 2

$$\begin{bmatrix} \Delta INNOV_{it} \\ \Delta FDI_{it} \\ \Delta IMP_{it} \\ \Delta R\&D_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} + \sum_{j=1}^p \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{13j} & \beta_{14j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} & \beta_{24j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} & \beta_{34j} \\ \beta_{41j} & \beta_{42j} & \beta_{43j} & \beta_{44j} \end{bmatrix} \begin{bmatrix} \Delta INNOV_{it-j} \\ \Delta FDI_{it-j} \\ \Delta IMP_{it-j} \\ \Delta R\&D_{it-j} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} u_{1it} \\ u_{2it} \\ u_{3it} \\ u_{4it} \end{bmatrix}$$

Model 3

$$\begin{bmatrix} \Delta INNOV_{it} \\ \Delta (R\&D \times FDI)_{it} \\ \Delta (R\&D \times IMP)_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_4 \end{bmatrix} + \sum_{j=1}^p \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{12j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} \end{bmatrix} \begin{bmatrix} \Delta INNOV_{it-j} \\ \Delta (R\&D \times FDI)_{it-j} \\ \Delta (R\&D \times IMP)_{it-j} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} u_{1it} \\ u_{2it} \\ u_{3it} \end{bmatrix}$$

3.5.3 Innovation performance. Innovation performance in this study is measured as the causal relationship between innovation and economic growth, with GDP being a proxy for economic growth. Innovation output is the main explanatory variable in this model. The export of innovations is also tested to examine its causal effect on economic growth. Arranging our variables in order of decreasing exogeneity, we estimate this relationship in model 4 below:

Model 4

$$\begin{bmatrix} \Delta GDP_{it} \\ \Delta EXP_{it} \\ \Delta INNOV_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{bmatrix} + \sum_{j=1}^p \begin{bmatrix} \beta_{11j} & \beta_{12j} & \beta_{12j} \\ \beta_{21j} & \beta_{22j} & \beta_{23j} \\ \beta_{31j} & \beta_{32j} & \beta_{33j} \end{bmatrix} \begin{bmatrix} \Delta GDP_{it-j} \\ \Delta EXP_{it-j} \\ \Delta INNOV_{it-j} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} u_{1it} \\ u_{2it} \\ u_{3it} \end{bmatrix}$$

For models 1 to 4, the short-run causal effects are determined by the significance of the *F*-stats of the VECM analysis, while long-run causalities are determined by the *t*-stats of the error correction term. The null hypothesis is that no causal relationship exists between variables, and a rejection of the same means there is short-run or long-run causal relationship between variables.

4. Results and discussions

4.1 Test for unit root

A test for stationarity of the variables is done using the CIPS test by Pesaran (2007). This test accounts for cross-sectional dependence among the variables. Cross-sectional dependence among variables could be due to globalization and international trade that make it easy for a shock in one economy to affect other economies as well (Nazlioglu, 2011). Hence, the CIPS best fits for this purpose. The test is conducted at three levels; first, the model is tested with constant, second without constant or trend, and third with constant and trend. The results of the CIPS unit root test, as shown in Table 1, indicate stationarity of the variables at first difference on all three lags selected.

4.2 Panel cointegration test

Results of the panel cointegration test are presented in Table 2. The results show there exists long-run cointegration among variables for the full sample and each region. The Pedroni test outcome shows that some of the statistics are significant across all samples, while that of the Kao test is also significant for all samples. These results show that the system can revert to its long-term equilibrium after any shock.

4.3 Results of model estimation

This section presents the results of the granger panel VECM causality of the variables tested in this study. The main variables of interest at the first stage include R&D, imports, and FDI for R&D intensity (represented by model 1). The variables of focus at the second stage are innovation output, R&D, imports, and FDI (model 2), and the interacting variables of R&D/imports and R&D/FDI presented in model 3. The final stage (innovation performance)

Variables	At level				At first difference				Order of integration
	Lag 1	Lag 2	Lag 3	Critical value (5%)	Lag 1	Lag 2	Lag 3	Critical value (5%)	
<i>Model with constant</i>									
GDP	-1.46	-1.42	-1.46	-2.2	-3.34	-3.34	-3.34	-2.2	I(1)
INNOV	-1.98	-2.06	-2.06	-2.2	-4.40	-4.41	-4.41	-2.2	I(1)
IMP	-1.41	-1.41	-1.41	-2.2	-3.54	-3.54	-3.54	-2.2	I(1)
EXP	-1.26	-1.26	-1.26	-2.2	-3.53	-3.53	-3.53	-2.2	I(1)
FDI	-2.63	-2.63	-2.51	-2.2	-5.28	-5.25	-5.17	-2.2	I(0) I(1)
R&D	-2.01	-2.01	-2.01	-2.2	-4.71	-4.71	-4.71	-2.2	I(1)
<i>Model with no constant nor trend</i>									
GDP	-0.31	-0.31	-0.31	-1.61	-3.16	-3.16	-3.16	-1.61	I(1)
INNOV	-1.43	-1.44	-1.44	-1.61	-4.33	-4.33	-4.33	-1.61	I(1)
IMP	-1.01	-1.01	-1.01	-1.61	-3.41	-3.41	-3.41	-1.61	I(1)
EXP	-0.57	-0.57	-0.57	-1.61	-3.57	-3.57	-3.57	-1.61	I(1)
FDI	-2.50	-2.50	-2.50	-1.61	-5.27	-5.27	-5.27	-1.61	I(0) I(1)
R&D	-0.84	-0.84	-0.84	-1.61	-4.66	-4.66	-4.66	-1.61	I(1)
<i>Model with constant and trend</i>									
GDP	-2.02	-2.02	-2.02	-2.72	-3.64	-3.64	-3.64	-2.72	I(1)
INNOV	-1.85	-1.79	-1.79	-2.72	-4.42	-4.42	-4.42	-2.72	I(1)
IMP	-1.62	-1.62	-1.62	-2.72	-3.67	-3.67	-3.67	-2.72	I(1)
EXP	-1.40	-1.40	-1.40	-2.72	-3.84	-3.84	-3.84	-2.72	I(1)
FDI	-2.98	-2.98	-2.98	-2.72	-5.27	-5.27	-5.27	-2.72	I(0) I(1)
R&D	-2.47	-2.47	-2.47	-2.72	-4.88	-4.88	-4.88	-2.72	I(1)

Table 1.
Results of unit root tests

Variables	Pedroni test		Kao test	
<i>Full sample</i>				
	Weighted stats		Group stats	
	Panel <i>v</i> -stat	-0.23 (0.591)	Group rho-stat	2.629 (0.995)
	Panel rho-stat	1.86 (0.968)	Group PP-stat	-2.02 (0.021)**
	Panel PP-stat	-1.92 (0.027)**	Group ADF-stat	-2.24 (0.012)**
	Panel ADF-stat	-2.01 (0.022)**		
<i>Africa</i>				
	Panel <i>v</i> -stat	9.67(0.000)***	Group rho-stat	1.03 (0.849)
	Panel rho-stat	-0.14 (0.442)	Group PP-stat	-1.75 (0.039)**
	Panel PP-stat	-3.56 (0.002)**	Group ADF-stat	-0.05 (0.479)
	Panel ADF-stat	-0.63 (0.264)		
<i>Asia</i>				
	Panel <i>v</i> -stat	-1.58 (0.943)	Group rho-stat	1.44 (0.925)
	Panel rho-stat	0.54 (0.706)	Group PP-stat	-2.62 (0.003)**
	Panel PP-stat	-2.46 (0.010)**	Group ADF-stat	-2.46 (0.006)**
	Panel ADF-stat	-2.21 (0.013)**		
<i>Europe</i>				
	Panel <i>v</i> -stat	-1.90 (0.971)	Group rho-stat	3.89 (1.000)
	Panel rho-stat	2.33 (0.990)	Group PP-stat	-8.05 (0.000)***
	Panel PP-stat	-4.57 (0.000)***	Group ADF-stat	-2.12 (0.017)**
	Panel ADF-stat	-3.53 (0.003)**		
<i>North America</i>				
	Panel <i>v</i> -stat	-0.26 (0.604)	Group rho-stat	0.12 (0.550)
	Panel rho-stat	-0.21 (0.415)	Group PP-stat	-2.35 (0.009)**
	Panel PP-stat	-1.52 (0.024)**	Group ADF-stat	-2.40 (0.007)**
	Panel ADF-stat	-2.15 (0.013)**		
<i>South America</i>				
	Panel <i>v</i> -stat	1.35 (0.087)*	Group rho-stat	-0.68 (0.248)
	Panel rho-stat	-1.25 (0.104)	Group PP-stat	-3.83 (0.0001)**
	Panel PP-stat	-4.05 (0.000)***	Group ADF-stat	-1.80 (0.035)**
	Panel ADF-stat	-1.75 (0.039)**		

Note(s): ***, ** and * denote a rejection of the null hypothesis of no cointegration at 1%, 5% and 10% respectively

Table 2.
Results of panel
cointegration test

is presented in model 4, and the variables of interest are GDP, innovation, and exports. Hence the analysis is based on these variables of interest. Model diagnostics were conducted using the Lagrange multiplier (LM) test for serial correlation, heteroskedasticity and normality. The results (in Table A1) show the *p*-values of the test statistics are greater than 5%, denoting an acceptance of the null hypotheses of no serial correlation, homoskedasticity and normally distributed residuals respectively.

4.3.1 R&D intensity. Estimation of the causal effects on imports and FDI on R&D is reported in Table 3. The results of the Wald *F*-test show that there exists a short-run causal relationship between imports and R&D for the entire sample, Asia and Europe. For Africa and North America, FDI has a short-run causal effect on R&D, while for South America, it is imports that have short-run causation with R&D. Bi-directional causalities are observed between imports and R&D for the full sample, and the Africa and Asia regions in the short-run. For other regions, the source of causation is mainly from imports to R&D. No

Independent variables Full sample	Short-run effects Dependent variables			Long-run effects ECT
	$\Delta R\&D_{it}$	ΔFDI_{it}	ΔIMP_{it}	<i>T</i> -stats
$\Delta R\&D_{it}$	–	6.97**	1.42	–3.281**
ΔFDI_{it}	3.86**	–	6.57**	–5.742***
ΔIMP_{it}	6.71**	1.55	–	–4.850**
<i>Africa</i>				
$\Delta R\&D_{it}$	–	2.94*	2.06	–2.568**
ΔFDI_{it}	3.89**	–	2.68*	3.994**
ΔIMP_{it}	1.17	2.21	–	0.788
<i>Asia</i>				
$\Delta R\&D_{it}$	–	3.21**	2.07	–2.644*
ΔFDI_{it}	2.96*	–	1.52	–4.230***
ΔIMP_{it}	6.97**	1.07	–	–3.735**
<i>Europe</i>				
$\Delta R\&D_{it}$	–	1.06	1.05	–3.270**
ΔFDI_{it}	8.78**	–	0.47	0.321
ΔIMP_{it}	18.75**	0.32	–	–3.950**
<i>North America</i>				
$\Delta R\&D_{it}$	–	0.77	1.22	–3.641**
ΔFDI_{it}	3.47**	–	1.89	–0.684
ΔIMP_{it}	1.12	0.37	–	–3.545**
<i>South America</i>				
$\Delta R\&D_{it}$	–	1.23	0.57	–1.139
ΔFDI_{it}	2.46*	–	2.57*	–3.654**
ΔIMP_{it}	2.69*	1.31	–	–0.108

Table 3.
VECM Granger
causality test for R&D
intensity

Note(s): ***, ** and * denote significance levels at 1%, 5% and 10% respectively

short-run bi-directional causation exists between FDI and R&D, the causation is mainly from FDI. The existence of a long-run relationship between imports and domestic R&D is further confirmed by the *T*-stat which is negative and significant. For the full sample, it is confirmed the *T*-statistics of the error correction term for both imports and FDI are significant, indicating the existence of long-run causalities with R&D. In the long-run, imports have causal relations with R&D for Asia, Europe and North America, while such causality exists from FDI to R&D for Asia and South America. Considering the full sample, short-run and long-run causation exist from imports and FDI to R&D.

These results show that the R&D activities of developing countries are significantly affected by imports from other countries. The short-run causality indicates that any changes in imports and FDI will have an immediate effect on domestic R&D investment. This effect will continue in the long term for regions where the long-run causal relationship is confirmed. In a similar study in Australia, [Salim and Bloch \(2009\)](#) established short-run causality between imports, exports, and R&D. These results show that for both technologically advanced and developing economies, international trade influences local R&D investments. Trade liberalization has over the years afforded developing countries access to technology from advanced economies ([Almeida and Fernandes, 2008](#)), and such technologies have proven very useful to the R&D efforts of developing economies in trying to catch up with technological advances.

Independent variables	Short-run effects				Long-run effects
	$\Delta INNOV_{it}$	ΔFDI_{it}	ΔIMP_{it}	$\Delta R\&D_{it}$	ECT <i>T</i> -stats
Full sample					
$\Delta INNOV_{it}$	–	6.45**	0.60	0.80	–2.304*
ΔFDI_{it}	5.76**	–	28.63***	8.69**	–2.924**
ΔIMP_{it}	27.43***	1.07	–	6.92**	–3.409**
$\Delta R\&D_{it}$	6.97**	1.76	29.50***	–	–3.072**
<i>Africa</i>					
$\Delta INNOV_{it}$	–	1.39	1.85	1.03	1.031
ΔFDI_{it}	0.59	–	12.67**	7.89**	–2.815**
ΔIMP_{it}	1.68	8.17**	–	1.78	–2.178*
$\Delta R\&D_{it}$	2.81*	0.21	11.81**	–	–1.938
<i>Asia</i>					
$\Delta INNOV_{it}$	–	1.37	0.64	1.42	–2.035*
ΔFDI_{it}	6.93**	–	1.48	3.30*	3.447**
ΔIMP_{it}	3.02*	2.65*	–	0.82	–3.572**
$\Delta R\&D_{it}$	2.53*	2.49*	0.61	–	–3.027**
<i>Europe</i>					
$\Delta INNOV_{it}$	–	1.56	1.86	0.19	–3.136**
ΔFDI_{it}	15.07***	–	1.05	3.84**	0.322
ΔIMP_{it}	3.60*	3.97**	–	0.25	–1.736*
$\Delta R\&D_{it}$	5.27**	0.88	0.74	–	4.870***
<i>North America</i>					
$\Delta INNOV_{it}$	–	1.39	0.30	0.38	–1.736*
ΔFDI_{it}	1.12	–	2.00	0.49	–4.192**
ΔIMP_{it}	2.40*	3.31**	–	2.72*	1.493
$\Delta R\&D_{it}$	1.19	0.94	0.40	–	5.062***
<i>South America</i>					
$\Delta INNOV_{it}$	–	0.97	2.48*	0.42	0.285
ΔFDI_{it}	2.84*	–	0.75	3.04**	2.234**
ΔIMP_{it}	2.50*	1.19	–	5.23**	0.523
$\Delta R\&D_{it}$	0.52	0.19	1.22	–	–2.019**

Note(s): ***, ** and * denote significance levels at 1%, 5% and 10% respectively

Table 4. VECM Granger causality test for innovation output

4.3.2 Innovation output. In the second stage of the model estimation, we test for the effects of R&D, imports, and FDI on indigenous innovation output. The results are shown in Table 4. The evidence from the *F*-stats of the Wald test shows that R&D, imports, and FDI all have short-run causalities with indigenous innovation output for the whole sample. These effects are largely influenced by effects in Asia, Europe, and South America. For Asia, all three variables are significant, while for Europe, significant causalities are from R&D and FDI, and for South America, the sources of causation are from imports and FDI. For Africa, the main source of causation in the short-run is from R&D, while for North America it is from imports. R&D and innovation output have a bidirectional causality with each other, while there is a unidirectional causality between imports, FDI, and innovation output. The *T*-stats of the error correction term for R&D and imports are negative and significant, showing that they have long-run causal relationships with innovation output for the full sample. FDI, however, does not show up strongly in the long-run as a source of causation for innovation output. For the individual regions, R&D and imports have long-run causal relations with innovation output in Africa and Asia, while that of Europe is mainly from R&D. For both North

Independent variables Full sample	Short-run effects Dependent variables			Long-run effects ECT T-stats
	$\Delta INNOV_{it}$	$\Delta(R\&D \times FDI)_{it}$	$\Delta(R\&D \times IMP)_{it}$	
$\Delta INNOV_{it}$	–	0.39	2.72*	–2.327*
$\Delta(R\&D \times FDI)_{it}$	13.34***	–	1.15	–3.744**
$\Delta(R\&D \times IMP)_{it}$	11.66***	1.15	–	–6.742***
<i>Africa</i>				
$\Delta INNOV_{it}$	–	1.66	3.43*	–2.991**
$\Delta(R\&D \times FDI)_{it}$	8.02**	–	0.62	–2.713***
$\Delta(R\&D \times IMP)_{it}$	4.77**	3.07*	–	1.285
<i>Asia</i>				
$\Delta INNOV_{it}$	–	0.41	1.44	–3.522**
$\Delta(R\&D \times FDI)_{it}$	12.28***	–	2.73*	–4.671***
$\Delta(R\&D \times IMP)_{it}$	11.36**	2.85*	–	2.651*
<i>Europe</i>				
$\Delta INNOV_{it}$	–	0.57	0.27	1.739
$\Delta(R\&D \times FDI)_{it}$	3.79**	–	0.86	–4.762**
$\Delta(R\&D \times IMP)_{it}$	3.31**	0.62	–	–3.450**
<i>North America</i>				
$\Delta INNOV_{it}$	–	0.16	1.65	–1.677*
$\Delta(R\&D \times FDI)_{it}$	2.48*	–	0.17	4.438***
$\Delta(R\&D \times IMP)_{it}$	2.82*	0.27	–	–4.328***
<i>South America</i>				
$\Delta INNOV_{it}$	–	0.86	1.52	0.717
$\Delta(R\&D \times FDI)_{it}$	8.25**	–	1.85	–3.667**
$\Delta(R\&D \times IMP)_{it}$	12.60***	2.25	–	–3.879**

Note(s): ***, ** and * denote significance levels at 1%, 5% and 10% respectively

Table 5.
VECM Granger
causality test for the
moderating roles of
imports and FDI in the
relationship between
R&D and innovation
output

and South America R&D and FDI are the main source of causation. Interestingly, FDI has a long-run causal relation with innovation output for only the South America region.

Results of the moderating roles of imports and FDI in the relationship between R&D and innovation output are reported in Table 5. The results indicate that an increasing amounts of foreign technologies enhance the effectiveness of local R&D in generating new knowledge. This complementarity between foreign technologies and internal R&D has significant short-run and long-run causalities with indigenous innovation output. While FDI has not shown strong causality for the full sample as seen in Table 4, these results show that when there is a complementarity between FDI and R&D, the strength of causation on innovation output increases. In regions where short-run causalities are not observed between the independent variables and innovation output as shown in Table 4, same complementarity has proven very effective. Except for Africa and Asia where the moderating role of imports is not significant in the long-run, for other regions imports are significant in moderating the long-run causal effect of R&D on innovation output.

These results point to significant influences of imports and FDI on innovation output through R&D. This outcome demonstrates that a complementarity between foreign technologies and local R&D will work more effectively, such that the more a country employs foreign technologies the more effective its R&D activities will be in generating new knowledge. Complementarity between two activities exists when the implementation of one activity increases the marginal returns directly associated with another (Stock and Watson, 2015; Carree et al., 2011). Our argument is based on the idea that adopting different sources of

knowledge simultaneously is more valuable to the innovation process than using each of them separately (Serrano-Bedia *et al.*, 2018). Arora and Gambardella (1990) demonstrated that there exists a complementarity between internal R&D and external technology sourcing, such that foreign technologies enhance the potential of R&D to lead to the production of new technologies. This assertion has been supported in this study, in that, in regions where no causal effects are observed from imports and FDI to innovation output, a complementarity between each of them and R&D have short-run and long-run causal effects. This evidence shows that imports and FDI that bring in novel technologies moderate the relationship between R&D and indigenous innovation output. Imported technologies and FDI activities that are targeted at indigenous R&D enhance the causal effect of investments in R&D on innovation output.

4.3.3 Productivity analysis. The results of the test for the performance of indigenous innovation are presented in Table 6. Innovation output and the export of innovations have both short-run long-run causal effects on economic growth for the full sample analyzed in this study. There exists both short and long-run bidirectional causality between economic growth and innovation output, and same results for GDP and exports. Bidirectional causalities in the short-run are also observed in some regions including Asia, Europe, and South America. For other regions, long-run causation is mainly from exports, except for Africa and North America where the main source of causation is from innovation. This evidence is very important as many countries are striving to produce novel technologies aimed at local and

Dependent variables	Short-run effects			Long-run effects
	ΔGDP_{it}	Independent variables ΔEXP_{it}	$\Delta INNOV_{it}$	ECT T-stats
Full sample				
ΔGDP_{it}	–	4.31**	2.70*	–2.218*
ΔEXP_{it}	18.21***	–	3.40**	–3.614**
$\Delta INNOV_{it}$	19.70***	2.23	–	–3.681**
<i>Africa</i>				
ΔGDP_{it}	–	7.79**	1.85	2.773**
ΔEXP_{it}	3.47*	–	6.67**	–2.615**
$\Delta INNOV_{it}$	6.34**	1.95	–	–1.345
<i>Asia</i>				
ΔGDP_{it}	–	3.34**	7.06**	–2.172*
ΔEXP_{it}	5.47**	–	1.07	–3.564**
$\Delta INNOV_{it}$	6.94**	7.18**	–	–2.216**
<i>Europe</i>				
ΔGDP_{it}	–	0.73	4.93**	–3.154*
ΔEXP_{it}	3.71**	–	0.73	–3.619**
$\Delta INNOV_{it}$	3.37**	3.97**	–	–2.618**
<i>North America</i>				
ΔGDP_{it}	–	0.63	0.55	–3.787**
ΔEXP_{it}	2.71*	–	0.42	0.867
$\Delta INNOV_{it}$	3.50**	0.27	–	–1.886*
<i>South America</i>				
ΔGDP_{it}	–	1.22	2.47*	–2.312
ΔEXP_{it}	3.60**	–	0.36	1.875*
$\Delta INNOV_{it}$	2.84*	2.61*	–	–1.930*

Note(s): ***, ** and * denote significance levels at 1%, 5% and 10% respectively

Table 6.
VECM granger
causality test for
innovation
performance

international consumption. Developing countries can benefit from innovation by domestic firms in making efforts to catch up with the developed world.

Changes in indigenous innovation have immediate and long term effects on economic growth for developing economies. Similarly, Pradhan *et al.* (2018) and Maradana *et al.* (2019) show that innovation is a long-run causative factor of economic growth in the EU region. The desire to catch up with the developed world will largely be influenced by the capability of developing countries to assimilate new technologies from other countries and use such technologies to develop new and diversified products. Exploiting opportunities that exist in international markets with new product ideas is also a significant influencer of economic growth. Growth in the economy is also found in this study to have a significant effect on the growth of indigenous innovation. This bidirectional causality makes it imperative for developing countries to pay more attention to local R&D and hence indigenous innovation.

5. Conclusions

This study analyzed how international trade influences indigenous innovation in developing economies. The study adopted the CDM model to do a three-stage estimation of the innovation process, including R&D intensity, innovation output, and innovation performance. Panel data of twenty developing countries from 1994 to 2018 was taken from the World Development Indicators (WDI) of the World Bank group for this analysis. The data was first analyzed for stationarity and cointegration before estimating the model. The series was seen to be integrated at order 1, and a subsequent test for cointegration showed a long-run cointegration among the variables analyzed. Therefore, a VECM Granger causality method was used to estimate the causal relationship between variables at each stage of the estimation process. The study resulted in the following conclusions.

First, as established by other scholars, imports and FDI are found to an immediate and long-term effect on local R&D investments. Second, the evidence shows that R&D, imports, and FDI have a short-run causal relationship with indigenous innovation output especially for Asia and Europe. However, for regions where the individual effect of local R&D, imports, and FDI do not have a short-run causal effect on innovation output, a complementarity between imports/R&D and FDI/R&D shows both short-run and long-run causal effects. These results indicate that imported technologies and FDI that are directly targeted at local R&D have an immediate and long-term effect on innovation output. Hence, it can be concluded that imports and FDI moderate the relationship between R&D and indigenous innovation. The evidence supports the fact that the import of technologies to aid local R&D activities is important for developing countries. Third, novel products and the export of innovations have causal effects on economic growth. Thus, endogenous economic growth through innovation by domestic businesses is established, but such an influence will be felt if developing countries can imbibe and use foreign inputs effectively.

From the results of this study, some policy recommendations can be made for developing countries to enhance their endogenous economic growth through indigenous innovation. First, government policies on indigenous innovation should facilitate access to resources by local businesses to enhance their R&D efforts. Second, financial support should be given to local businesses in various sectors of the economy to help them build the required level of capacity to diffuse foreign technologies. This will encourage businesses to import more of inputs to production processes rather than finished goods. Third, governments in developing countries should make a conscious effort to form trade partnerships with other countries to enable local producers to gain access to such external markets with limited restrictions.

The findings of this study give critical insights into how international trade influences indigenous innovation in developing countries albeit limited to middle-income countries.

Future studies can expand this study to cover low-income countries to bring out further findings and policy implications that are critical to the growth of developing economies.

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Further reading

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Appendix 1

Study variables

- (1) Gross Domestic Product (GDP): This variable is employed in this study as a proxy for economic growth. It is an important dependent variable since the study seeks to measure how indigenous innovation impacts on economic growth in developing economies. GDP is expressed as constant USD 2010.
- (2) Indigenous Innovation (INNOV): This is a measure of innovation output generated by residents of each country under study. In this study, trademark applications by residents is used as a proxy for indigenous innovation. Trademark applications is increasingly preferred as a proxy

- for innovation due to the availability of data especially for developing economies (Crass *et al.*, 2019; Flikkema *et al.*, 2019). INNOV is expressed as the total number of trademark applications by residents.
- (3) Research and Development (R&D): R&D is an important measure of the intensity of innovation efforts at firm and country levels. It is measured in this study as total expenditure on research and development for each country. This variable is used as the main dependent variable at the first stage of the estimated CDM model. R&D is a percentage of GDP on annual basis.
 - (4) Imports (IMP): This is a measure of the total amount of goods and services imported into a country for the period of study. The import of products is a major activity associated with international trade, and it is therefore important to measure its impact on innovation by indigenous businesses. This will help policymakers determine if imports have any effect on local innovation efforts. Imports is expressed as constant USD 2010.
 - (5) Foreign Direct Investments (FDI): FDI inflows is employed as another economic activity that can potentially impact on local innovation efforts. The absorption of foreign technologies associated with FDI has often been pointed out as a catalyst for innovation by domestic firms. Hence the need to test its effect on indigenous innovation in this study. FDI is expressed as constant USD 2010.
 - (6) Exports (EXP): This represents the exports of goods and services. It is employed in this study as a measure of how the exports of innovations impact economic growth. It is expressed as constant USD 2010.

Appendix 2

	H_0	Model 1	Model 2	Model 3	Model 4
VEC residual Normality tests	Residuals are multivariate normal	0.505 (0.873)	0.032 (0.926)	0.017 (0.895)	0.072 (0.787)
VEC residual serial correlation LM test	No serial correlation at lag order h	2.711 (0.974)	1.112 (0.341)	0.415 (0.411)	1.377 (0.240)
VEC residual heteroskedasticity	Residual are homoskedastic	1.320 (0.381)	1.591 (0.207)	1.047 (0.306)	0.790 (0.373)

Note(s): Parentheses contain the p -values of the test statistics

Table A1. Tests for normality, autocorrelation and heteroskedasticity

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