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Article

# Reassessing the role of technology for economic growth: A comparative study of Asian developing economies

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**Abstract:** The role of technology in stimulating economic growth needs to be reexamined considering current heightened economic conditions of Asian developing Economies. This study conducts a comparative analysis of technology proxied by R&D expenditures alongside macroeconomic variables crucial for economic growth. Monthly time-series data from 1990 to 2019 were analyzed using a vector error correction model (VECM), revealing a significant impact of technology on the economic growth of India, Pakistan, and the Philippines. However, in the cases of Indonesia, Malaysia, Thailand, and Bangladesh, macroeconomic indicators were found more crucial to their economic growth. Results of Granger causality underlined the relationship of R&D expenditures and macroeconomic variables with GDP growth rates. Sensitivity analyses endorsed robustness of the results which highlighted the significance and originality of this study in economic growth aligned with sustainable development goals (SDGs) for developing countries.

**Keywords:** sustainable economic growth; R&D expenditure; macroeconomics; granger causality; ex-post forecast

## 1. Introduction

The assertion posited by Borowy and Schmelzer (2017), underscores the imperative of equitable wealth distribution alongside the pursuit of economic growth, signaling a critical imperative for nations to embark upon trajectories of sustainable development. While some nations have achieved commendable economic growth and efficaciously addressed societal well-being, considerable disparities persist in growth trajectories among nations, especially among Asian developing economies, endowed with abundant resources (Amar and Pratama, 2020; Fang et al., 2022; Gatto and Sadik-Zada, 2021). Economic development is closely linked with economic growth (Rajnoha and Lesnikova, 2022), conventionally gauged through metrics such as Gross Domestic Product (GDP) serving as a principal indicator of economic vitality (Petrakis, 2020, p. 31). The divergent levels of technological advancement evident within developing nations in Asia underscore the imperative of directing resources towards Research and Development (R&D) expenditures to enrich growth patterns and boost competitiveness within the global marketplace (Sahin, 2019).

Theoretically, the responsiveness to technological shifts and the strategic allocation of R&D expenditures produce a profound impact on explaining the macroeconomic environment and fostering economic growth (Ahmad and Zheng, 2023; Boeing et al., 2022). Developed nations consistently prioritize R&D investment to efficaciously steward resources, whereas developing nations often struggle with inadequate resource management and inconsistent policymaking (Bruijn and Antonides, 2020; Tran et al., 2020). In this manner, these nations lag in technological advancement, missing out on the benefits it offers in the development of foundational infrastructure and requisite technology for economic growth (Dinh et al., 2019; Nui et al., 2022; Shahid et al., 2023). In the year 2021, Asia and the Pacific witnessed a robust economic growth of 6.5%, convalescing from the economic deceleration precipitated by the pandemic. Nonetheless, this momentum narrowed to 4.0% in 2022, accompanied by challenges such as inflation, exchange rate depreciation, and increasing unemployment, as highlighted by the International Monetary Fund (IMF, 2022).

To sustain growth, developing economies must innovate to secure a competitive edge within the global marketplace, create jobs, strengthen infrastructure, and elevate living standards (Fukuda, 2020; Giri et al., 2021; Korinek and Stiglitz, 2021). The United Nations (UN) Sustainable Development Goals (SDGs), disseminated in 2015, underscore the need for developing economies to attain a growth rate of 7% by 2030 through collaborative partnerships and concerted sustainable development endeavours (Iqbal et al., 2023; Morina et al., 2020). Despite endeavours at structural reform, the majority of Asian countries, specifically South and South East Asia, have faded in the international market as GDP growth and governmental revenue of these nations has been declining (Chien et al., 2022; Frankema, 2024; Gomez et al., 2021). Despite having all the resources necessary for sustainable economic growth, these nations are being trapped in a middle-income trap that must be overcome to manage sustainable economic growth (Qi and Chu, 2022). By virtue of their abundant human and natural resources, a substantial proportion of their GDP is derived from primary industry and the service sector, primarily destined for export to developing regions (Redmond and Nasir, 2020; Sun et al., 2020). This dearth of quality products conducive to export to developed nations is ascribed to technological backwardness, thereby adversely impacting productivity and progress towards SDGs (UNCTAD, 2022; World Bank, 2022). Redirecting R&D investment for technology improvement and industry-centric initiatives holds the potential to amplify export levels, and employment opportunities, and moderate the adverse impact of inflation on the economy (Ahmad et al., 2022; Li et al., 2022).

Although, the role of technology has been proven and endorsed by extant literature but role of R&D investment in technology's role in economic growth considering the macroeconomic indicators still lacking in the existing field of study (Soete et al., 2022). Existing studies either focused on the consequences R&D and innovation in economic growth or they (Shahbaz et al., 2022) or related economic growth with green-house gas emission (Haller et al., 2022), which necessitates a theoretical description related to R&D, economic growth and SDGs as highlighted by Shahid et al. (2024). Hence, findings of this study not only abridge these gaps by examining the role of R&D for economic growth but also significantly contribute theoretically in the existing body of knowledge. Further, Salehi et al. (2020) suggested that, for sustainable economic growth, developing nations have to allocate financial resources for technology development in consideration of macroeconomic indicators which will help developing nations a sustainable growth. In view of the empirical and theoretical intervals, this study intends:

1) To examine the combine impact of R&D expenditures and macroeconomic variables on economic growth of developing Asian economies.
2) To explore the economic impact of R&D expenditures on economic growth of developing Asian economies.
3) To provide a comparative ex-post forecast which can help developing nations to make right decision for R&D investment for higher economic growth.

The combined effect of R&D and macroeconomic indicators is particularly important for developing Asian economies as they are rich in resources but striving for economic growth. This way, this is the first to examine the combined effect of R&D expenditures, foreign direct investment, trade balance, employment rate and inflation rate which are crucial for the countries under study. Examining this effect provides a comprehensive understanding in light of the current heightened economic situation and growth disparities among the countries under study. In provision of comparative ex-post forecast helps the economies under study to adjust their investment patterns and its effect on GDP growth rate which may contribute to the SDGs. Theoretically, this study re-aligns the theoretical framework for the role of R&D in economic growth, addressing the modern needs of developing nations that have been overlooked in recent literature as highlighted by Shahid et al. (2024).

Rest of the study composed of section 2 which provides theoretical underpinning related to R&D and economic growth followed by a literature review of in macroeconomic indicators explaining their relationship with the GDP growth rate. The methodology employed in this study is outlined in section 3, followed by the presentation of results in section 4. Section 5 delves into a discussion of the findings and their implications.

## 2. Literature review

### 2.1. Theoretical framework

It has been widely acknowledge that technological output serves as a fundamental driver of economic growth. At the primer of numerous growth models and theories lies the recognition that technology plays a pivotal role in fostering long-term economic development. Various economic theories explain the importance of innovation and technological progress in advancing economic growth. For instance, exogenous and endogenous growth models underscore the significance of technological advancement, positing that innovation is a key driver of economic progress beyond traditional factors of production (Romer, 1990; Solow, 1957). In subsequent years, economists such as Easterly and Levine (2001), have emphasized the importance of human and physical capital alongside technology. However, the economic impact of R&D investment has often been neglected in macroeconomic estimation, necessitating the incorporation of R&D along with macroeconomic indicators to forecast economic growth patterns, particularly in developing parts of the world (Brynjolfsson and Unger, 2023). This underscores the importance of examining the combined effects of R&D investment and macroeconomic indicators on the GDP growth rate.

Given the imperative and extensive body of literature, several studies have explored the impact of technology and macroeconomic factors on country-level economic growth, there remains a gap in comprehensively examining the effects of technology and macroeconomic indicators in constructing a cross-country growth in pursuant to economic growth under SDG-8. Specifically, R&D expenditures pursuant to GDP growth has been considered important and literature signifies it importance for sustainable economic growth.

## 2.2. R&D expenditures and GDP growth

Role of technology is R&D expenditure represents the financial investment made by the economies towards technological advancement which further adds to the quality of products and services through innovation (OCED, 2002, p. 152; Simonova et al., 2021). For developing economies, investment in technology through R&D is helpful in abridging the economic and technological disparities which enable these nations to compete in international markets (Baruk, 2022; Shkarlet et al., 2020). In a study conducted by Olaoye et al. (2021) across four African nations, the role of R&D expenditure and government intervention in fostering growth and development was evaluated, revealing a notable 29% surge in GDP. Similarly, Charutawephonnukoon et al. (2021) observed a significant positive correlation between technology development and economic development through a comparative analysis of R&D investment and GDP growth rate among ASEAN countries. However, in developing countries, the lack of adequate financial resources poses a significant challenge to fostering R&D investment which necessitates governments to comprehend the macroeconomic environment to wisely invest R&D in a targeted way. Thereby, this understanding favours the economic activities which lead to enhanced productivity, an increase in employment rate, and increased consumption patterns, subsequently impacting inflation (Hobbs et al., 2021; Zghidi et al., 2016). Economists agree that inflation has a strong negative relationship with economic growth (Barguellil et al., 2018; Nitami and Hayati, 2021) which underscores the need to account for inflation which discussing sustainable development through economic growth (Adaramola and Dada, 2020; Morina et al., 2020).

## 2.3. Macroeconomic factors and GDP growth rate

While discussing about the role of inflation in economic growth, the UNCTAD[1] Statistics Handbook (2018) reported that the inflation rate and economic growth through GDP growth rate have strong relational ties with the exchange rate as no economy can survive without international trade relationships. Meyer and Hassan (2024) conducted a study among South African economies considering the role inflation using and applied ARDL method on quarterly data. The authors found a significant role of inflation on economic growth and suggested stable monetary policy for sustainable economic growth. Among other indicators, continuous appreciation in exchange rate index many affect the inflation which results in a potential price hike in developing countries which further affects production and export levels (Meyer and Hassan, 2020; Yang et al., 2022). Later, Obeng-Amponsah and Owusu (2023) conducted a study to examine the relationship between foreign direct investment (FDI), employment and economic growth and found that FDI does not affect employment and economic growth. In addition, they found that technology has a significant impact on this relationship to enhance economic growth rate. In the latest literature, Barbary and Tawfiq (2024) conducted an empirical study and found a significant cointegration between inflation, exports and foreign direct investment (FDI). They added that FDI inflow only results in a balanced export level which highlights the importance of a favorable trade balance for a higher GDP growth rate.

The inter-relationship between production, inflation and FDI can be converted in favor through technological advancement. Hence, considering the challenges of developing Asian economies, this study accounts for R&D expenditures as a proxy of technological advancement with trade balance[2], exchange rate, employment rate and inflation rate to examine their impact on the GDP growth rate. This way, it can examine the impact of technology and macroeconomic variables on GDP growth rate which adds empirically to the existing understanding of economic growth to promote SDGs among developing Asian nations.

## 3. Material and methods

### 3.1. Data and sample description

This study leveraged data from seven dynamic emerging economies, each with diverse technological landscapes and notable variations in GDP growth rates, for a comprehensive cross-country examination (Eberhardt and Teal, 2011). The authors considered using monthly data of each country ranging from 1990 to 2019 with intention to avoid misleading output created by huge variations caused by COVID-19 (Stoto et al., 2022). These countries comprise Bangladesh, India, Indonesia, Malaysia, Pakistan, the Philippines, and Thailand. As these nations exhibit considerable natural and human resources with a great growth potential (Oh et al., 2015) in addition to the growth disparities exist among these nations so results can provide better understanding pursuant to objective of this study (Bernadine and Zhan, 2023). Further, the results can be applied among countries of same characteristics which will enhance the originality of this study (Korinek et al., 2021). Based on the given literature considering the current heightened situation of these nations, the following general function has been developed for the study.

$$\mathrm{GDP} = f(\mathrm{R\&D}, \mathrm{NX}, \mathrm{EXR}, \mathrm{EMR}, \mathrm{INF}) \tag{1}$$

where, GDP= GDP growth rate, NX= trade balance, EXR= exchange rate, EMR= employment rate, INF= inflation rate, and $\varepsilon$ = error term.

Data on the variables have been downloaded from different sources as presented by **Table 1**. In cases, where monthly data was missing, the authors utilized the match-sum data technique to convert yearly and quarterly data into monthly data, making it more suitable for the final analysis (Godil et al., 2021; Sharif et al., 2019; Suki et al., 2020).

**Table 1.** Description of variables and data sources.

| Variable | Meaning | Measurement | Theoretical Justification | Possible impact | Data Source |
|---|---|---|---|---|---|
| GDP | Gross domestic product | GDP growth rate. | Classical theory of growth states that increase in GDP means economic growth. | + | WDI and IMF |
| R&D | Research and development expenditures | Expenditures made on R&D as aggregate % of GDP | Investment in R&D has positive effects on innovation and modernization which further results in economic growth. | + | WDI and Statista |
| NX | Exports minus imports (trade balance) | At current US$ (Million) | A favourable trade balance boosts economic activities and enhances economic growth levels. | + | WDI and Trading Economics |
| EMR | Employment rate | Percentage of labour force | A resource indicator which multiplies to the economic growth as human capital. | + | World Bank, and ILO |
| EXR | Exchange rate | Local currency to US$ (at current) | It summarizes the transactions through trade and has a greater impact on the growth rate. | − | World Bank, and IMF |
| INF | Inflation rate | Consumer price index (CPI) | Changes in aggregate demand result in inflation which affects growth. | − | IMF |

Source: Authors' own presentation.
Notes: IMF (International Monetary Fund), ILO = International Labour Organization, and WDI are world development indicators by the World Bank.

### 3.2. Model specification and hypotheses development

After downloading the time-series data, the authors normalized it using MS Excel, including the calculation of trade balance using exports and imports data, to make it appropriate for final analysis. For analysis, this study specified the following econometric model.

$$GDP_t = \beta_0 + R\&D_t + NX_t + EXR_t + EMR_t + INF_t + \varepsilon_t \quad (2)$$

For each country, the following hypothesis has been tested using above economic model.

$H_{01}$: There is no relationship between R&D expenditures (R&D), foreign direct investment (FDI), net exports (NX), exchange rate (EXR), employment rate (EMR), inflation rate (INF) and economic growth.

$H_{A1}$: There is a relationship between R&D expenditures (R&D), foreign direct investment (FDI), net exports (NX), exchange rate (EXR), employment rate (EMR), inflation rate (INF) and economic growth.

### 3.3. Analysis procedure

As macroeconomic data normally found non-stationary at a level (Hill, 2010), so we proceed with the unit-root test using Augmented Dicky-Fuller (ADF) (1981) and Philip-Perron (1998) tests. For data stationarity, the following hypothesis has been developed.

$H_0$ = the series has a unit root

$H_A$ = the series does not have a unit root

After checking data stationarity, this study proceeded to run the final analysis using appropriate analysis technique based on the results of Johansen's co-integration test. In the existence of data stationarity at the first level I(1), the vector error correction model (VECM) seemed an explicit solution incorporating short-run dynamics and the long-run equilibrium (Anderson et al., 2002). After examination of long-run and short-run relationships, this study tested residual diagnostics for multicollinearity and heteroscedasticity as they have been considered adequate for residual diagnostics in the presence of unit root tests (Laskar and King, 1997). In later stages, we run the ex-post forecast for policy suggestions based on the comparative accuracy of the analyses.

## 4. Results and analysis

### 4.1. Trend analysis

**Figure 1** shows the trend analysis of the GDP growth rate of the countries under study. It is evident from the figure that before 2018, the GDP of Bangladesh, the Philippines and Thailand was having an increasing trend while for India and Thailand, there was almost a stable GDP growth rate trend. The GDP of Indonesia and Pakistan showed a decreasing trend before 2018. Unanimously, during 2019, the trends of GDP growth rate among countries under study tends to decrease.

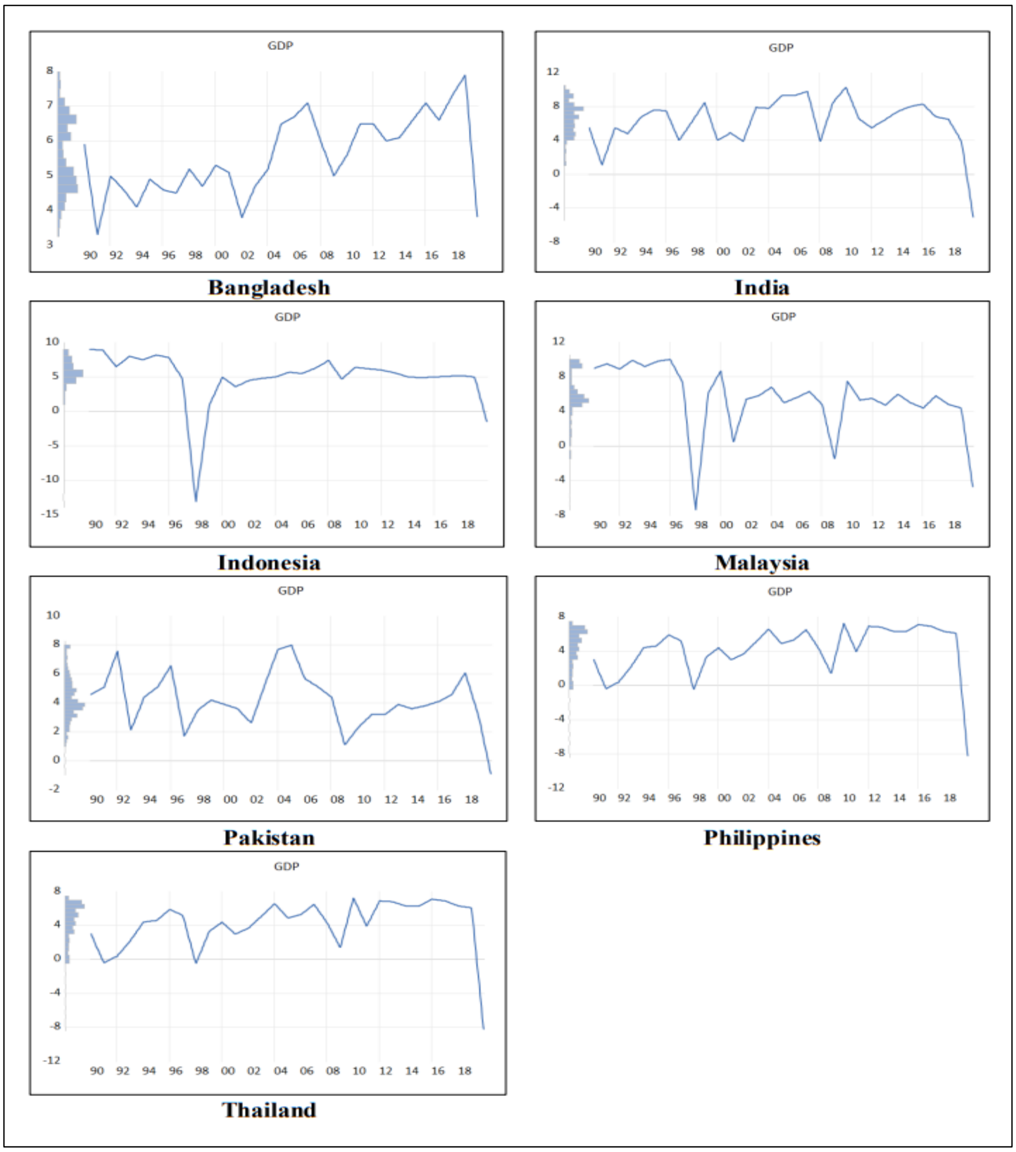


**Figure 1.** GDP growth rate trend analysis.

### 4.2. Unit-root tests

The results of the ADF and Phillips-Perron tests revealed that most of the data

**Table 2.** Results of unit root tests.

| | Bangladesh | | | | India | | | |
|---|---|---|---|---|---|---|---|---|
| | ADF | | Phillips-Perron Test | | ADF | | Phillips-Perron Test | |
| Variables | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) | I(0) | I(1) |
| GDP | −0.98 | −3.11*** | −0.79 | −3.49*** | −1.29 | −3.38*** | −1.02 | −3.78*** |
| R&D | −3.18* | −4.82*** | −2.02** | −5.35*** | 0.44 | −2.69** | 0.79 | −2.96*** |
| NX | −1.27 | −2.91*** | −1.24 | −3.27*** | −1.53 | −3.45*** | −0.97 | −3.78*** |
| EXR | 1.72 | −3.29*** | 3.83 | −3.48*** | 1.63 | −4.11*** | 3.19 | −4.37*** |
| EMR | −0.74 | −3.54*** | −0.82 | −3.89*** | −1.33 | −2.98*** | −1.92* | −3.39*** |
| INF | −1.42 | −4.47*** | −0.89 | −4.93*** | −1.56 | −4.39*** | −1.41 | −4.85*** |
| | **Indonesia** | | | | **Malaysia** | | | |
| | **ADF** | | **Phillips-Perron Test** | | **ADF** | | **Phillips-Perron Test** | |
| **Variables** | **I(0)** | **I(1)** | **I(0)** | **I(1)** | **I(0)** | **I(1)** | **I(0)** | **I(1)** |
| GDP | −2.74* | −4.22*** | −1.92* | −4.68*** | −2.68** | −4.67*** | −1.77* | −5.18*** |
| R&D | −0.15 | −4.58*** | 1.05 | −5.07*** | 0.57 | 4.31*** | 1.5 | −4.71*** |
| NX | −2.00* | −4.24*** | −1.28 | −4.65*** | −1.34 | −4.09*** | −0.85 | −4.42*** |
| EXR | 0.63 | −3.77*** | 1.61 | −4.09*** | 0.52 | −3.61*** | 1.06 | −3.89*** |
| EMR | −0.29 | −3.27*** | 0.34 | −3.48*** | 0.99 | −2.97*** | 1.48 | −3.15*** |
| INF | −3.33* | −4.61*** | −2.10* | −5.09*** | −2.01** | −4.92*** | −1.24 | −5.45*** |
| | **Pakistan** | | | | **Philippines** | | | |
| | **ADF** | | **Phillips-Perron Test** | | **ADF** | | **Phillips-Perron Test** | |
| **Variables** | **I(0)** | **I(1)** | **I(0)** | **I(1)** | **I(0)** | **I(1)** | **I(0)** | **I(1)** |
| GDP | −1.81 | −3.91*** | −1.27 | −4.34*** | −1.74 | −2.36** | −1.18 | −2.77** |
| R&D | −1.47 | −5.65*** | −0.91 | −6.07*** | −1.80* | −5.51*** | −0.89 | −5.93*** |
| NX | −2.02 | −2.85*** | −1.32 | −3.21*** | −1.92 | −2.85*** | −1.51 | −2.17** |
| EXR | 1.95 | −2.67** | 5.28 | −2.76*** | 0.16 | −3.93*** | 0.72 | −4.28*** |
| EMR | −0.78 | −4.03*** | 0.25 | −4.12*** | −1.04 | −1.87** | −1.37 | −2.19** |
| INF | −1.37 | −4.37*** | −0.79 | -4.80*** | −2.97 | −4.44*** | −2.95* | −4.89*** |
| | **Thailand** | | | | | | | |
| | **ADF** | | **Phillips-Perron Test** | | | | | |
| **Variables** | **I(0)** | **I(1)** | **I(0)** | **I(1)** | | | | |
| GDP | −2.68 | −4.08*** | −2.19** | −4.52*** | | | | |
| R&D | −0.01* | −3.31*** | 2.31 | −3.54*** | | | | |
| NX | −2.71 | −3.37*** | −1.69* | −3.69*** | | | | |
| EXR | −0.35 | −4.53*** | −0.11 | −5.01*** | | | | |
| EMR | −0.95 | −3.62*** | −1.49 | −3.87*** | | | | |
| INF | −2.36 | −4.79*** | −1.74* | −5.33*** | | | | |

Notes: GDP = gross domestic product growth rate, R&D = R&D expenditures, FDI = foreign direct investment, NX = net exports, EXR = exchange rate, EMR = employment rate, and INF = inflation rate.

did not meet the necessary criteria for stationarity at level I(0) except some variables like R&D and GDP where $p < 0.10$ for Bangladesh, Indonesia, and Malaysia respectively (see **Table 2**) while all the variables become stationary at fist difference I(1). GDP growth rate, R&D expenditures, trade balance, exchange rate, employment rate and inflation non-stationarity at level I(0) while stationary at I(1) so it results in rejection of null hypothesis for data stationarity.

## 4.3. Cointegration rank test

All variables under examination in this study have exhibited stationarity at the level I(1), thereby satisfying the prerequisite for conducting a cointegration rank test at 0.05 level of significance using MacKinnon-Haug-Michelis (1999) criteria for *p*-values. The Schwarz Criteria for Johansen cointegration tests revealed the prevalence Trace tests over Max-Eigen values with number of 3 for Bangladesh, 1 for India, 2 for Indonesia, 2 for Malaysia, 2 for Pakistan, 2 for the Philippines, and 1 for Thailand at 0.05 critical value (see Appendix). Further, normalized co-integration coefficients confirmed the existence of a long-run relationship using GDP growth rate as endogenous variables.

## 4.4. Vector error correction model results

### 4.4.1. Error correction model (ECM)-long-run relationship

Following, **Table 3** shows the results of Johansen's co-integration test for the assessment of the relationship among macroeconomic stationary variables. The table shows the existence of long-run cointegration among variables under each country to set for running the analysis using VECM.

**Table 3.** Results of Johansen co-integration test.

| Country | | D(GDP) | D(R&D) | D(NX) | D(EXR) | D(EMR) | D(INF) |
|---|---|---|---|---|---|---|---|
| Bangladesh | COINTEQ1 | −0.002 | 0.003*** | 0.006 | 0.008 | −0.005 | −0.007** |
| | *t*-stat | [−0.271] | **[6.757]** | [0.576] | [0.332] | [−1.009] | [−4.008] |
| India | COINTEQ1 | −0.002 | −0.001 | −0.004** | −0.003 | 0.001 | −0.011** |
| | *t*-stat | [−0.599] | [−0.603] | [−4.387] | [−0.747] | [0.133] | [−4.525] |
| Indonesia | COINTEQ1 | 0.028** | −0.001* | −0.008* | −6.196** | 0.002* | −0.103*** |
| | *t*-stat | [4.677] | **[−2.195]** | [−2.624] | [−4.513] | [1.659] | [−6.089] |
| Malaysia | COINTEQ1 | −0.017** | 0.000 | 0.003 | 0.001** | −0.000 | 0.005** |
| | *t*-stat | [−4.875] | [1.409] | [1.149] | [3.941] | [−0.883] | [4.024] |
| Pakistan | COINTEQ1 | −0.002* | 0.001*** | 0.004** | −0.005** | −0.000 | −0.008*** |
| | *t*-stat | [−2.149] | **[7.028]** | [3.978] | [−2.514] | [−0.869] | [−6.497] |
| Philippines | COINTEQ1 | −0.006* | 0.001*** | −0.006* | 0.015** | −0.001 | 0.014** |
| | *t*-stat | [−1.859] | **[5.689]** | [-2.401] | [3.998] | [−0.565] | [4.538] |
| Thailand | COINTEQ1 | −0.003 | 0.000** | −0.005** | 0.001** | 0.003*** | −0.005*** |
| | *t*-stat | [−1.365] | **[4.742]** | [−2.385] | [3.675] | [6.215] | [−3.201] |

Notes: GDP = gross domestic product growth rate, R&D = R&D expenditures, NX = net exports, EXR = exchange rate, EMR = employment rate, and INF = inflation rate.

The *t*-stat values shown in bold show the significance level where $p < 0.05$.

From the above table, it has been evident that R&D has a long-run relationship with the GDP growth rate for all the countries under study except for India and Malaysia. The values of *t*-statistics are [−0.6032] and [1.4088] for these countries and lower than the threshold value.

### 4.4.2. Vector error correction model-short-run relationship adjustments

The VECM models' equations have been formed in the following way for each country.

$$\Delta GDP_t = \beta_0 + \beta_1 \Delta R\&D_{t-1} + \beta_2 \Delta NX_{t-1} + \beta_3 \Delta EXR_{t-1} + \beta_4 \Delta EMR_{t-1} + \beta_5 \Delta INF_{t-1} + \varepsilon_t$$

The results of VECM for short-run correction of the relationship have been presented in the following **Table 4**. The t-stat values for Bangladesh, Indonesia, Malaysia, and Thailand were found greater than 1.65 [3.4671, 3.3867, 5.1943, and 3.9483 respectively] which means that $\beta_0$ and $\beta_1$ for these nations are significant at 0.05 level of significance. For India, Pakistan and the Philippines t-stat values are less than 1.65 showing no short-run relationship between GDP growth rate and R&D expenditures for technology advancement. Further, the values of *R*-squared and adjusted *R*-squared show that the models for each country have significant predictability with the exogenous variables with GDP growth rate for economic growth. Hence, the model is reliable and robust in nature for each country under study.

**Table 4.** Results of VECM analysis.

| | **Bangladesh** | **India** | **Indonesia** | **Malaysia** | **Pakistan** | **Philippines** | **Thailand** |
|---|---|---|---|---|---|---|---|
| D(GDP(−1)) | 0.9145 | 0.9614 | 0.8732 | 0.8849 | 0.8975 | 0.9342 | 0.9116 |
| | **[37.1560]** | **[31.1605]** | **[13.8344]** | **[30.6567]** | **[38.7947]** | **[29.9389]** | **[32.9624]** |
| D(R&D(−1)) | 0.0018 | 1.04067 | 0.9133 | 0.1716 | 0.3524 | 0.1539 | 2.3699 |
| | **[3.4671]** | [0.5452] | **[3.3867]** | **[5.1943]** | [0.9114] | [0.1713] | **[3.9483]** |
| D(NX(−1)) | −0.0227 | −0.0653 | −0.0473 | −0.0536 | 0.0047 | −0.0099 | 0.0298 |
| | [−1.2264] | [−1.1173] | [−0.6990] | [−1.4017] | [0.2545] | [−0.2821] | [1.1424] |
| D(EXR(−1)) | 0.0025 | 0.0425 | 0.0001 | 0.0562 | −0.0056 | 0.0042 | −0.0325 |
| | [0.2042] | [1.9806] | [0.4626] | [0.0868] | [−0.6442] | [0.1959] | [−1.4036] |
| D(EMR(−1)) | 0.0534 | −0.0314 | −0.1121 | 0.7068 | 0.0411 | 0.0871 | 0.0439 |
| | [1.0661] | [−0.3536] | [−0.7862] | [2.6219] | [0.5089] | [0.7121] | [0.3297] |
| D(INF(−1)) | 0.0014 | 0.0182 | 0.0021 | 0.0482 | −0.0166 | 0.0108 | −0.0005 |
| | [0.1586] | [0.7392] | [0.1065] | [0.6066] | [−0.9636] | [0.3915] | [−0.0099] |
| C | 0.0005 | −0.0094 | 0.0059 | 0.0122 | 0.0006 | 0.0031 | 0.0104 |
| | [0.1943] | [−1.4657] | [0.5989] | [1.1737] | [0.1203] | [0.5024] | [1.1710] |
| ***R*-squared** | **0.8523** | **0.8424** | **0.8205** | **0.8085** | **0.8259** | **0.8605** | **0.8169** |
| **Adj. *R*-sq.** | **0.8493** | **0.8393** | **0.8169** | **0.8047** | **0.8224** | **0.8577** | **0.8133** |

## 4.5. Results of granger's causally

**Table 5**, below, represents the causal relationships between GDP growth rate, R&D expenditures, net exports, exchange rates, employment rate, and inflation rate for each country under study. It is important to mention that Granger's causality has been calculated by applying Ad-hoc selection methods considering the appropriate macroeconomic data (Jones, 1989).

In Bangladesh, R&D unilaterally influences GDP, while FDI shows a reciprocal relationship with GDP, rejecting the null hypothesis for FDI. Net exports and inflation rate unilaterally impact GDP. Similarly, in India, R&D spending and foreign direct investment unilaterally affect GDP, while other variables exhibit significant causal relationships with India's GDP. For Indonesia, R&D influences the GDP growth rate, rejecting the null hypothesis for R&D but accepting it for R&D to GDP. GDP growth rate interacts bi-directionally with FDI, net exports, and employment rate, rejecting the null hypothesis for these variables. The exchange rate does not influence GDP, but GDP influences the exchange rate, establishing a unilateral causal relationship. In Malaysia, GDP influences R&D unilaterally, while net exports and employment rates exhibit bidirectional causality with GDP. The inflation rate is influenced by GDP, indicating a unilateral causal relationship. In Pakistan, R&D unilaterally affects GDP, rejecting the null hypothesis for R&D to GDP, while accepting it for GDP to R&D. In the Philippines, net exports, exchange rate, employment rate, and inflation rate bi-directionally influence GDP growth rate, rejecting the null hypothesis for these variables. R&D impacts GDP unilaterally, while GDP does not influence R&D. In Thailand, R&D expenditures impact GDP growth rate, while FDI, net exports, and inflation rate exhibit bidirectional causality with GDP, rejecting the null hypothesis for these relationships. The exchange rate and employment rate unilaterally influence GDP.

**Table 5.** Results of Granger's causality.

| | **Indonesia** | | **Malaysia** | | **Philippines** | | **Thailand** | | **Bangladesh** | | **India** | | **Pakistan** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hypothesis:** | ***F*-Stat** | ***P*** | ***F*-Stat** | ***P*** | **F-Stat** | ***P*** | ***F*-Stat** | ***P*** | ***F*-Stat** | ***P*** | ***F*-Stat** | ***P*** | ***F*-Stat** | ***P*** |
| R&D does not Granger Cause GDP | 4.35 | 0.04 | 0.21 | 0.64 | 29.15 | 0.00 | 4.89 | 0.03 | 3.81 | 0.05 | 1.33 | 0.25 | 5.32 | 0.02 |
| GDP does not Granger Cause R&D | 0.39 | 0.53 | 25.41 | 0.00 | 1.95 | 0.16 | 0.74 | 0.39 | 1.74 | 0.19 | 98.75 | 0.00 | 1.59 | 0.21 |
| NX does not Granger Cause GDP | 37.03 | 0.00 | 21.13 | 0.00 | 23.47 | 0.00 | 60.39 | 0.00 | 9.58 | 0.00 | 10.98 | 0.00 | 37.37 | 0.00 |
| GDP does not Granger Cause NX | 66.85 | 0.00 | 15.64 | 0.00 | 91.39 | 0.00 | 61.33 | 0.00 | 0.99 | 0.32 | 86.98 | 0.00 | 225.37 | 0.00 |
| EXR does not Granger Cause GDP | 0.07 | 0.79 | 1.36 | 0.25 | 24.25 | 0.00 | 4.37 | 0.04 | 2.29 | 0.13 | 20.47 | 0.00 | 14.27 | 0.00 |
| GDP does not Granger Cause EXR | 8.17 | 0.00 | 21.78 | 0.00 | 11.95 | 0.00 | 0.98 | 0.32 | 0.08 | 0.78 | 12.93 | 0.00 | 21.27 | 0.00 |
| EMR does not Granger Cause GDP | 6.14 | 0.01 | 6.92 | 0.01 | 153.20 | 0.00 | 0.40 | 0.53 | 0.72 | 0.39 | 27.79 | 0.00 | 10.49 | 0.00 |
| GDP does not Granger Cause EMR | 12.96 | 0.00 | 20.04 | 0.00 | 5.35 | 0.02 | 97.52 | 0.00 | 2.92 | 0.08 | 18.72 | 0.00 | 2.78 | 0.09 |
| INF does not Granger Cause GDP | 11.17 | 0.00 | 1.51 | 0.22 | 11.27 | 0.00 | 8.66 | 0.00 | 5.42 | 0.02 | 14.55 | 0.00 | 16.31 | 0.00 |
| GDP does not Granger Cause INF | 0.30 | 0.58 | 7.57 | 0.01 | 18.18 | 0.00 | 24.91 | 0.00 | 1.91 | 0.17 | 10.72 | 0.00 | 30.06 | 0.00 |
| | **Observations** | | | | | | | | | | | | | **359** |

Notes: GDP = gross domestic product growth rate, R&D = R&D expenditures, NX = net exports, EXR = exchange rate, EMR = employment rate, and INF = inflation rate.

## 4.6. Residual diagnostics

### 4.6.1. Multicollinearity test

Based on the pertinent data model, **Table 6** presents the results of the multicollinearity assessment conducted through the variance inflation factor (VIF). The centered VIF values for Indonesia, Malaysia, Philippines, Thailand, India, and Pakistan fall within the range of 1.0590 to 2.8994, notably below the threshold of 3, thus indicating the absence of multicollinearity issues within the datasets (James et al., 2013). Furthermore, the calculated VIF for EMR in the context of Bangladesh exceeds 5 but remains below 10, thereby remaining within the acceptable range (VIF < 10) as specified by O'Brien (2007), and signifying the absence of multicollinearity concerns within the dataset. Consequently, it may be inferred that the exogenous variables across all seven (7) countries exhibit no significant correlation with one another, underscoring the robustness of the analytical outcomes and facilitating effective explanatory insights.

**Table 6.** Multicollinearity test results.

| | **Centered VIF** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Bangladesh** | **India** | **Indonesia** | **Malaysia** | **Pakistan** | **Philippines** | **Thailand** |
| R&D | 1.237 | 1.312 | 1.114 | 1.243 | 1.931 | 1.971 | 1.107 |
| NX | 1.709 | 1.129 | 2.899 | 1.859 | 2.853 | 1.458 | 1.449 |
| EXR | 3.643 | 1.376 | 1.339 | 1.977 | 2.465 | 2.798 | 1.171 |
| EMR | 7.471 | 1.165 | 1.059 | 1.049 | 1.212 | 1.407 | 1.687 |
| INF | 1.595 | 1.030 | 2.101 | 1.272 | 1.538 | 2.007 | 1.202 |

Notes: GDP = gross domestic product growth rate, R&D = R&D expenditures, NX = net exports, EXR = exchange rate, EMR = employment rate, and INF = inflation rate.

### 4.6.2. Heteroscedasticity test

From **Table 7**, it is evident that for Bangladesh, Indonesia, and Pakistan, errors do not occur randomly in the initial autoregressive model at a significance level of 0.05. The appropriate measure employed for addressing heteroscedasticity within the time series regression for these countries was the Breusch-Pagan-Godfrey test, which effectively mitigated the issue (Berger et al., 2017). Consequently, this study rejects the null hypotheses pertaining to the presence of heteroscedasticity in Indonesia, Bangladesh, and Pakistan. Similarly, for Malaysia, Philippines, Thailand, and India, the null hypotheses were also rejected utilizing the HAC Newey-West test (see **Table 7**). While the introduction of new variables, alongside the application of the Breusch-Pagan-Godfrey method, could potentially resolve the issue, such an approach was not recommended due to the utilization of R&D expenditures as an estimator of GDP growth rate alongside macroeconomic variables in this study (Can et al., 2017; Lazarus et al., 2018). Consequently, the HAC test was applied to ensure robust and reliable results for these countries. Consequently, the execution of VAR regression for VECM across all models adhered to a normal distribution, thereby satisfying the fundamental assumptions for time series data analysis.

**Table 7.** Results of heteroscedasticity tests.

| Country | F-stat | Prob | Decision |
|---|---|---|---|
| Bangladesh | 52.730 | 0.081 | Do not reject $H_0$: The is no heteroscedasticity (at $\alpha > 0.05$) |
| India | 47.067 | 0.127 | Do not reject $H_0$: The is no heteroscedasticity (at $\alpha > 0.10$) |
| Indonesia | 3.56 | 0.196 | Do not reject $H_0$: The is no heteroscedasticity (at $\alpha > 0.10$) |
| Malaysia | 5.504 | 0.183 | Do not reject $H_0$: The is no heteroscedasticity (at $\alpha > 0.10$) |
| Pakistan | 16.564 | 0.084 | Do not reject H0: The is no heteroscedasticity (at $\alpha > 0.05$) |
| Philippines | 11.509 | 0.055 | Do not reject $H_0$: The is no heteroscedasticity (at $\alpha > 0.05$) |
| Thailand | 14.736 | 0.088 | Do not reject $H_0$: The is no heteroscedasticity (at $\alpha > 0.05$) |

Note: heteroscedasticity test at 0.05 level of significance.

### 4.7. Model's simulation and ex-post forecasting accuracy

Previous researchers suggested that values of Room Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentile Error (MAPE) and Theil's inequality can be used to assess a model's forecasting accuracy (Armstrong and Collopy, 1992). According to the results given in the **Table 8**, values of RMSE near to 1 and ranged from 0.0531 and 1.4292 which are for Bangladesh and Malaysia respectively. The values of MAE are also near to one (1) while, notably, values of Theil's Inequality coefficients for all the countries found near to zero. In this manner, we can say that VECM models run for each country are significantly reliable with minimum chances of error.

**Table 8.** Models accuracy results.

| Criteria | Bangladesh | India | Indonesia | Malaysia | Pakistan | Philippines | Thailand |
|---|---|---|---|---|---|---|---|
| RMSE | 0.053 | 0.922 | 1.095 | 1.429 | 1.007 | 1.035 | 1.450 |
| MAE | 0.408 | 0.623 | 0.751 | 1.119 | 0.791 | 1.000 | 1.072 |
| MAPE | 7.510 | 21.201 | 28.854 | 0.000 | 18.079 | 0.000 | 34.369 |
| Theil Ineq. coef. | 0.047 | 0.145 | 0.091 | 0.197 | 0.159 | 0.139 | 0.237 |

Note: RMSE = root mean square error, MAE = mean absolute error, MAPE = mean absolute percentage error, and Theil Ineq. Coef. = Theil inequality coefficient.

### 4.8. Sensitivity analysis

Considering the results of model accuracy, this study also examined model simulation through sensitivity analysis given in **Figure 2**. The figure presents the impulse response function between GDP and R&D at the degree of freedom innovation with ± 2 analytic standard error. For understanding, it may be noted that the blue line in the center of each figure shows the impulse response function for each country while the upper and lower lines show a 95% confidence interval in the impulse response function calculation. From the figure, we can see that IRF for dynamic responses to the GDP growth shocks in the system show downward trends for Indonesia and Pakistan while for other countries, it shows upward forecasting trends.

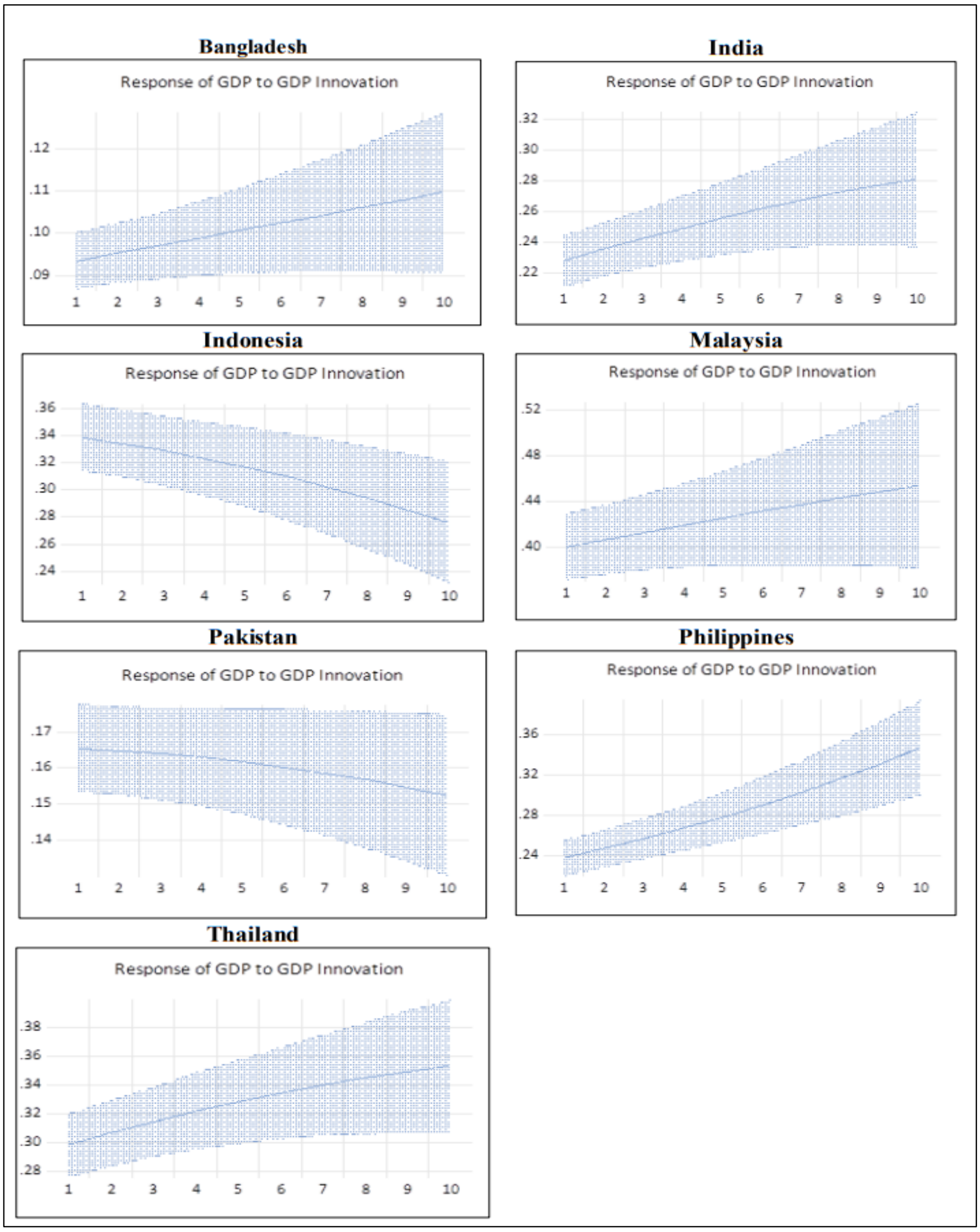


**Figure 2.** Sensitivity analysis.

Source: Author's presentation based on EViews output.

## 5. Discussion and conclusion

This study tested null hypotheses for seven developing nations of Asia including; Bangladesh, India, Indonesia, Malaysia, Pakistan the Philippines and Thailand for economic growth comparison considering technology through R&D expenditures. The results show varied results which have been shown in the following **Table 9**.

The GDP growth rate of all the countries except India and Malaysia has a long-run relationship calculated through cointegration tests which means that the GPD growth rate and technology for Bangladesh, Indonesia, Pakistan, the Philippines, and Thailand move together over time, adjusting back towards an equilibrium level after short-term disturbances. The existence of significance in the short run suggests that the variables included in the model are co-integrated and move together in the long run despite short-term fluctuations. In this way, results of this study helps to understand the adjustments made by VECM back followed by the structural shocks in GDP growth in an empirical way.

**Table 9.** Summary of long-run and short-run relationship.

| Country | Effect | |
|---|---|---|
| | **Long-run** | **Short-run** |
| Bangladesh | Yes | Yes |
| India | No | Yes |
| Indonesia | Yes | No |
| Malaysia | No | Yes |
| Pakistan | Yes | Yes |
| Philippines | Yes | No |
| Thailand | Yes | Yes |

Adjustments through the applied method provides valuable insights into R&D expenditures, macroeconomics, and GDP growth rates among the countries under study. Especially in the case of Bangladesh, the null hypothesis has been rejected thereby confirming the strong relationship existence between R&D, trade balance, and GDP growth rate however, diverging on the aspect of the causality relationship as Pamela and Indrawati (2022) observed in their study. In contrast, considering the significance for India, lead this study not to reject the null hypothesis which can be concluded that R&D, particularly the government-directed R&D expenditures, has a nominal impact on GDP growth which confirms the prior body of literature by Qamaruzzam et al. (2020) and Rakhmatillo et al. (2021). This gives meaning to the exogenous growth theory discouraging involvement of the government for increased level of economic growth.

Exchanging rates, employment rate, and inflation rate are more important for economic growth in Indonesia compared to R&D expenditures, suggesting that macroeconomics outweighs R&D in view of achieving a better economy which is in line with the study of Pascual et al. (2020). For Thailand, the indicators coincide with Ciobanu (2021) which highlighted the importance of R&D expenditures towards technological advancement and GDP growth. The results in the case of Pakistan underline the importance of R&D expenditures in terms of sustainable economic growth. The investigations conducted by this study clearly show the bidirectional causality among the principal variables i.e., GDP growth rate and R&D expenditures which provides nuanced understanding with comparative accuracy for the policymakers in developing Asian nations regarding sustainable economic growth. Further, it helps in understanding of the complex relationship between technology, macroeconomics, and economic growth hence, in adjusting the policies on time for achieving SDGs in presence of limited R&D investment capacity.

## 5.1. Contributions of the study

### 5.1.1. Theoretical contributions

Basically, two growth theories that have emphasized the role of technology through R&D which are: first, endogenous growth theory; and second, exogenous theory of growth. In the endogenous growth model, it is considered that innovation is its own cause generated by means of R&D activities which further lead to economic growth. The results of this study underscore the importance of R&D considering their economic impact among Asian developing economies. The study highlights that R&D's role for economic growth is crucial as laid down by the growth models (e.g., endogenous growth theory) and adds that these developing nations should take balanced action considering their economic situation. In prevailing rapidly volatile circumstances, it may be necessary to align priorities with macroeconomic factors (Lee, 2020) so that the benefits of technology can be obtained in the best way purely in theoretical terms as highlighted by Shahid et al. (2024) rather than focusing on R&D and economic growth spillover effects on the environment (Wang and Zhang, 2021). This way, the results of the study help to re-adjust the theoretical understanding of technology-led economic growth.

#### 5.1.2. Policy suggestions

A report presented by Ulku (2004), underscored the issue faced by Asian developing economies in extending their capacity to fund R&D for economic growth. In addition, these nations faced numerous financial challenges, especially for last five years which limits their capacity to invest in R&D, and highlighted the need of understanding macroeconomics because technology along with the available resources can play important role for rapid economic growth (Shahid et al., 2023). Considering this phenomenon, this study can be applied among developing nations in order to get sustainable economic growth, as highlighted by Easterly and Levine (2001), pursuant to SDG-8. Hence, this study integrates technology and macroeconomic indicators, investigating the role of R&D investment for economic growth across economies under study. Consequently, the findings significantly add to the current understanding of economic growth as a corridor to the sustainable development of developing countries, as advocated by Yoruk et al. (2023). Moreover, by focusing on the developing economies of Asia, this study yields a practical and generalizable understanding by providing actionable insights for policymakers to foster sustainable economic growth as underscored by the UN. In particular, the use of macroeconomic policies among these nations can increase employment levels and moderate the rate of inflation, hence sparking growth and development. The policy makers among these nations can spend available resources in a prudent way so that long term benefits can be promoted by investing in technology that will yield positive trade balances, favour trade-balance, and reduce the rates of inflation.

### 5.2. Conclusion

The study unravel the complex relationship between technology, the macroeconomic indicators, and economic growth in Asian nations which comes in a comparative understanding of these critical factors in the current heightened economic situation of developing Asia. We used R&D expenditures as a proxy of technology, along with other key economic factors using monthly data to ensure robust and reliable results. This way, it provides clear guidelines considering that developing economies are not able to bear the burden of investment in R&D as easily as financial at large in presence of unfavourable macroeconomics. Due to this reason, we applied an efficient analysis technique to investigate the relationship and influence of exogenous variables against the endogenous variable so that results can be generalized in order to extend the findings to achieve economic growth. Hence, the findings of this study can be helpful to make better decisions about the investment of scarce financial resources in R&D. The fact that it proved correct means that the adopted method had a deep understanding of this complex and dynamic relationship which exhibit alike variations over time.

The VECM adjusted the equilibrium following short-term disturbances, providing meticulous insights into the economic dynamics. By focusing on developing economies in Asia, the study aims to provide actionable insights for policymakers to foster sustainable economic growth in line with the UN's development goals. A clear understanding of macroeconomics can aid in wise decision-making related to investment in R&D for technological change, which, in turn, can positively influence the trade balance, employment rate, and inflation rate, as well as increase FDI inflow. Collectively, these factors are conducive to sustainable development and economic growth in developing countries.

### 5.3. Limitations and future call

The potential limitation during this study was the data collection that was handled through different data sourced from reputable institutions such as the World Bank, IMF, ILO, and Statista and formed the backbone of this study. Particularly in accessing R&D expenditure data for Bangladesh and Pakistan, the author overcame these challenges by resorting to alternative sources like these data sources and annual reports. Although the study effectively achieves its goal of comparative economic analysis across diverse Asian nations, its limitation lies in excluding economically significant countries. However, reframing this as a potential avenue for future exploration could transform it into an opportunity for further research.

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## Notes

[1] UNCTAD stands for the United Nations Conference on Trade and Development and is an intergovernmental platform to promote trade development among developing countries.

[2] The trade balance has been calculated by exports-imports and presented in this study as 'NX'.

## References

Adaramola, A. O., & Dada, O. (2020). Impact of inflation on economic growth: evidence from Nigeria. Investment Management and Financial Innovations, 17(2), 1-13. https://doi.org/10.21511/imfi.17(2).2020.01

Ahmad, M., & Zheng, J. (2022). The Cyclical and Nonlinear Impact of R&D and Innovation Activities on Economic Growth in OECD Economies: a New Perspective. Journal of the Knowledge Economy, 14(1), 544–593. https://doi.org/10.1007/s13132-021-00887-7

Amar, S., & Pratama, I. (2020). Exploring the link between income inequality, poverty reduction and economic growth: An ASEAN perspective. International Journal of Innovation, Creativity and Change, 11(2), 24-41.

Anderson, R. G., Hoffman, D. L., & Rasche, R. H. (2002). A vector error-correction forecasting model of the US economy. Journal of Macroeconomics, 24(4), 569-598. https://doi.org/10.1016/S0164-0704(02)00067-8

Armstrong, J. S., & Collopy, F. (1992). Error measures for generalizing about forecasting methods: Empirical comparisons. International journal of forecasting, 8(1), 69-80. https://doi.org/10.1016/0169-2070(92)90008-W

Barbary, M. M., & Tawfiq, A. R. (2024). The impact of foreign direct investment on exports in the kingdom of Saudi Arabia (an empirical study). Journal of Infrastructure, Policy and Development, 8(6), 4990. https://doi.org/10.24294/jipd.v8i6.4990

Barguellil, A., Ben-Salha, O., & Zmami, M. (2018). Exchange Rate Volatility and Economic Growth. Journal of Economic Integration, 33(2), 1302–1336. https://doi.org/10.11130/jei.2018.33.2.1302

Baruk, J. (2022). Research and Development Expenditures in the Sector of Polish Enterprises as an Instrument of Research and Development Policy. Marketing of Scientific and Research Organizations, 43(1), 25–52. https://doi.org/10.2478/minib-2022-0002

Berger, A. N., Klapper, L. F., & Turk-Ariss, R. (2017). Bank competition and financial stability. In: Handbook of Competition in Banking and Finance. Edward Elgar Publishing. https://doi.org/10.4337/9781785363306.00018

Bernadine N'D. A., & Zhan, S. (2022). Towards a successful learning process of companies from developing countries involved in offshore outsourcing: proposal for an integrative analytical framework. Critical Perspectives on International Business, 19(3), 355–398. https://doi.org/10.1108/cpoib-07-2021-0059

Boeing, P., Eberle, J., & Howell, A. (2022). The impact of China's R&D subsidies on R&D investment, technological upgrading and economic growth. Technological Forecasting and Social Change, 174. https://doi.org/10.1016/j.techfore.2021.121212

Borowy, I., & Schmelzer, M. (2017). Introduction. History of the Future of Economic Growth, 1–26. https://doi.org/10.4324/9781315543000-1

Bruijn, E. J. de, & Antonides, G. (2020). Determinants of financial worry and rumination. Journal of Economic Psychology, 76. https://doi.org/10.1016/j.joep.2019.102233

Brynjolfsson, E., & Unger, F. (2023). Macroeconomics of artificial intelligence. Finance & Development, 60(4).

Can, M., Doğan, B., & Değer, O. (2017). The Relationship between research & development investment expenditure, foreign direct investment and economic growth. Journal of Applied Economic Sciences, 12(1), 58-62.

Charutawephonnukoon, P., Jermsittiparsert, K., & Chienwattanasook, K. (2021). Impact of high technology exports, patent applications and research and development expenditure on economic growth: evidence from ASEAN countries. Psychology and Education, 58(2), 1956-1972.

Chien, F., Chau, K. Y., Aldeehani, T. M., et al. (2022). Does external debt as a new determinants of fiscal policy influence sustainable economic growth: implications after COVID-19. Economic Change and Restructuring, 55(3), 1717–1737. https://doi.org/10.1007/s10644-021-09365-1

Ciobanu, A. M. (2020). The Impact of FDI on Economic Growth in Case of Romania. International Journal of Economics and Finance, 12(12), 81. https://doi.org/10.5539/ijef.v12n12p81

Dickey, D. A., & Fuller, W. A. (1981). Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. Econometrica, 49(4), 1057. https://doi.org/10.2307/1912517

Dinh, T. T. H., Vo, D. H., The Vo, A., et al. (2019). Foreign Direct Investment and Economic Growth in the Short Run and Long Run: Empirical Evidence from Developing Countries. Journal of Risk and Financial Management, 12(4), 176. https://doi.org/10.3390/jrfm12040176

Easterly, W. (2001). What have we learned from a decade of empirical research on growth? It's Not Factor Accumulation: Stylized Facts and Growth Models. The World Bank Economic Review, 15(2), 177–219. https://doi.org/10.1093/wber/15.2.177

Eberhardt, M., & Teal, F. (2011). Econometrics for grumblers: a new look at the literature on cross-country growth empirics. Journal of Economic Surveys, 25(1), 109–155. https://doi.org/10.1111/j.1467-6419.2010.00624.x

Fang, W., Liu, Z., & Putra, A. R. S. (2022). Role of research and development in green economic growth through renewable energy development: Empirical evidence from South Asia. Renewable Energy, 194, 1142–1152. https://doi.org/10.1016/j.renene.2022.04.125

Frankema, E. (2024). From the Great Divergence to South-South Divergence: New comparative horizons in global economic history. Journal of Economic Surveys. https://doi.org/10.1111/joes.12609

Fukuda, K. (2020). Science, technology and innovation ecosystem transformation toward society 5.0. International Journal of Production Economics, 220, 107460. https://doi.org/10.1016/j.ijpe.2019.07.033

Giri, M., Bista, G., Singh, P. K., et al. (2021). Climate change vulnerability assessment of urban informal settlers in Nepal, a least developed country. Journal of Cleaner Production, 307, 127213. https://doi.org/10.1016/j.jclepro.2021.127213

Godil, D. I., Sharif, A., Ali, M. I., et al. (2021). The role of financial development, R&D expenditure, globalization and institutional quality in energy consumption in India: New evidence from the QARDL approach. Journal of Environmental Management, 285, 112208. https://doi.org/10.1016/j.jenvman.2021.112208

Gomez, E. T., Cheong, K. C., & Wong, C. Y. (2021). Regime Changes, State-Business Ties and Remaining in the Middle-Income Trap: The Case of Malaysia. Journal of Contemporary Asia, 51(5), 782–802. https://doi.org/10.1080/00472336.2021.1933138

Grossman, G. M., & Helpman, E. (1991). Trade, knowledge spillovers, and growth. European economic review, 35(2-3), 517-526. https://doi.org/10.1016/0014-2921(91)90153-A

Haller, A. P., Ștefănică, M., Butnaru, G. I., et al. (2023). Climate neutrality through economic growth, digitalisation, eco-innovation and renewable energy in European countries. Kybernetes. https://doi.org/10.1108/k-09-2022-1254

Hill, J. B. (2010). On tail index estimation for dependent, heterogeneous data. Econometric Theory, 26(5), 1398–1436. https://doi.org/10.1017/s0266466609990624

Hobbs, S., Paparas, D., & E. AboElsoud, M. (2021). Does Foreign Direct Investment and Trade Promote Economic Growth? Evidence from Albania. Economies, 9(1), 1. https://doi.org/10.3390/economies9010001

IMF. (2022). World Economic Outlook (October 2024). Available online: https://www.imf.org/external/datamapper/datasets/WEO (accessed on 3 May 2023).

Iqbal, A., Tang, X., & Rasool, S. F. (2022). Investigating the nexus between CO2 emissions, renewable energy consumption, FDI, exports and economic growth: evidence from BRICS countries. Environment, Development and Sustainability, 25(3), 2234–2263. https://doi.org/10.1007/s10668-022-02128-6

James, G., Witten, D., Hastie, T., et al. (2013). An Introduction to Statistical Learning. In: Springer Texts in Statistics. Springer New York. https://doi.org/10.1007/978-1-4614-7138-7

Jones, J. D. (1989). A comparison of lag–length selection techniques in tests of Granger causality between money growth and inflation: evidence for the US, 1959–86. Applied Economics, 21(6), 809–822. https://doi.org/10.1080/758520275

Laskar, M. R., & King, M. L. (1997). Modified Wald test for regression disturbances. Economics Letters, 56(1), 5-11. https://doi.org/10.1016/S0165-1765(97)00128-6

Lazarus, E., Lewis, D. J., Stock, J. H., et al. (2018). HAR Inference: Recommendations for Practice. Journal of Business & Economic Statistics, 36(4), 541–559. https://doi.org/10.1080/07350015.2018.1506926

Lee, D. (2019). The role of R&D and input trade in productivity growth: innovation and technology spillovers. The Journal of Technology Transfer, 45(3), 908–928. https://doi.org/10.1007/s10961-019-09717-0

Li, W., & Ullah, S. (2022). Research and development intensity and its influence on renewable energy consumption: evidence from selected Asian economies. Environmental Science and Pollution Research, 29(36), 54448–54455. https://doi.org/10.1007/s11356-022-19650-9

MacKinnon, J. G., Haug, A. A., & Michelis, L. (1999). Numerical distribution functions of likelihood ratio tests for cointegration. Journal of Applied Econometrics, 14(5), 563-577.

Meyer, D. F., & Hassan, A. S. (2020). Analysis of the impact of exchange rate volatility on the South African Government bond market. International Journal of Economics and Finance, 12(2), 271-289.

Meyer, D. F., & Hassan, A. S. (2024). Analysis of the optimal inflation rate in the economic growth process of a developing country: The case of South Africa. Journal of Infrastructure, Policy and Development, 8(6), 3607. https://doi.org/10.24294/jipd.v8i6.3607

Morina, F., Hysa, E., Ergün, U., et al. (2020). The Effect of Exchange Rate Volatility on Economic Growth: Case of the CEE Countries. Journal of Risk and Financial Management, 13(8), 177. https://doi.org/10.3390/jrfm13080177

Nitami, S. A., & Hayati, B. (2021). Relationship Between Crude Oil Price Fluctuations, Economic Growth, Inflation, and

Exchange Rate in Indonesia 1967-2019. AFEBI Economic and Finance Review, 6(2), 83. https://doi.org/10.47312/aefr.v6i2.334

Niu, M., Zhang, S., Zhang, N., et al. (2022). Progress in the Research of Environmental Macroeconomics. Sustainability, 14(3), 1190. https://doi.org/10.3390/su14031190

O'brien, R. M. (2007). A Caution Regarding Rules of Thumb for Variance Inflation Factors. Quality & Quantity, 41(5), 673–690. https://doi.org/10.1007/s11135-006-9018-6

Obeng-Amponsah, W., & Owusu, E. (2023). Foreign direct investment, technological transfer, employment generation and economic growth: new evidence from Ghana. International Journal of Emerging Markets. https://doi.org/10.1108/ijoem-02-2022-0200

OECD. (2002). Measuring the Information Economy, Organisation for Economic Co-Operation and Development. Available online: https://www.oecd.org/sti/ieconomy/1835738.pdf (accessed on 3 May 2023).

Oh, H., Seo, D., Kim, J., et al. (2015). Assessment and evaluation of national human resource development system competitiveness in emerging countries. Asia Pacific Education Review, 16(3), 477–490. https://doi.org/10.1007/s12564-015-9390-9

Olaoye, I. J., Ayinde, O. E., Ajewole, O. O., et al. (2020). The role of research and development (R&D) expenditure and governance on economic growth in selected African countries. African Journal of Science, Technology, Innovation and Development, 13(6), 663–670. https://doi.org/10.1080/20421338.2020.1799300

Pamela, Q., & Indrawati, L. R. (2022). Effect of Inflation, Exports, and Employment on Economic Growth in Central Java. Research Horizon, 2(5), 501–510. https://doi.org/10.54518/rh.2.5.2022.501-510

Pascual, K. C. A., Dionisio, C. P., & Capulla, R. (2020). The relationship of real Gross Domestic Product (GDP), inflation, and unemployment in the Philippines (1970-2011). International Journal of Research Studies in Education, 9(2). https://doi.org/10.5861/ijrse.2020.5804

Petrakis, P. E. (2020). Theoretical Approaches to Economic Growth and Development. Springer International Publishing. https://doi.org/10.1007/978-3-030-50068-9

Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. Biometrika, 75(2), 335–346. https://doi.org/10.1093/biomet/75.2.335

Qamruzzaman, M., Mehta, A. M., Khalid, R., et al. (2021). Symmetric and asymmetric effects of financial innovation and FDI on exchange rate volatility: Evidence from South Asian countries. The Journal of Asian Finance, Economics and Business, 8(1), 23-36.

Qi, Y., & Chu, X. (2022). Development of the digital economy, transformation of the economic structure and leaping of the middle-income trap. China Political Economy, 5(1), 14–39. https://doi.org/10.1108/cpe-09-2022-0012

Rajnoha, R., & Lesnikova, P. (2022). Sustainable Competitiveness: How Does Global Competitiveness Index Relate to Economic Performance Accompanied by the Sustainable Development? Journal of Competitiveness, 14(1), 136–154. https://doi.org/10.7441/joc.2022.01.08

Rakhmatillo, E., Kobilov, A., Makhmudov, S. (2021). Foreign direct investment, economic growth and employment: var method for uzbekistan. Journal of Contemporary Issues in Business and Government, 27(02). https://doi.org/10.47750/cibg.2021.27.02.187

Redmond, T., & Nasir, M. A. (2020). Role of natural resource abundance, international trade and financial development in the economic development of selected countries. Resources Policy, 66, 101591. https://doi.org/10.1016/j.resourpol.2020.101591

Romer, P. M. (1990). Endogenous Technological Change. Journal of Political Economy, 98(5, Part 2), S71–S102. https://doi.org/10.1086/261725

Sahin, B. E. (2019). Impact of high technology export on economic growth: an analysis on Turkey. Pressacademia, 8(3), 165–172. https://doi.org/10.17261/pressacademia.2019.1123

Salehi, M., Daemi Gah, A., Akbari, F., et al. (2020). Does accounting details play an allocative role in predicting macroeconomic indicators? Evidence of Bayesian and classical econometrics in Iran. International Journal of Organizational Analysis, 29(1), 194–219. https://doi.org/10.1108/ijoa-10-2019-1902

Schindler, M., Korinek, A., & Stiglitz, J. (2021). Technological Progress, Artificial Intelligence, and Inclusive Growth. IMF Working Papers, 2021(166), 1. https://doi.org/10.5089/9781513583280.001

Shahbaz, M., Sharma, R., Sinha, A., et al. (2021a). Analyzing nonlinear impact of economic growth drivers on CO2 emissions: Designing an SDG framework for India. Energy Policy, 148, 111965. https://doi.org/10.1016/j.enpol.2020.111965

Shahbaz, M., Soliman, A., & Ullah, S. (editors). (2021b). Economic Growth and Financial Development. Springer International Publishing. https://doi.org/10.1007/978-3-030-79003-5

Shahbaz, M., Song, M., Ahmad, S., et al. (2022). Does economic growth stimulate energy consumption? The role of human capital and R&D expenditures in China. Energy Economics, 105, 105662. https://doi.org/10.1016/j.eneco.2021.105662

Shahid, M. K., Khin, A. A. and Seong, L. C. (2023). Systematic Review of Research and Development Expenditures and Sustainable Economic Development in ASEAN Countries. In: CoMBInES-Conference on Management, Business, Innovation, Education and Social Sciences. pp. 140-156. https://journal.uib.ac.id/index.php/combines/article/view/7684

Shahid, M. K., Khin, A. A., Seong, L. C., et al. (2024). Mapping the Relationship of Research and Development Expenditures and Economic Growth through Bibliometric Analysis: A Theoretical Perspective. Journal of the Knowledge Economy. https://doi.org/10.1007/s13132-024-01781-8

Sharif, A., Shahbaz, M., & Hille, E. (2019). The Transportation-growth nexus in USA: Fresh insights from pre-post global crisis period. Transportation Research Part A: Policy and Practice, 121, 108–121. https://doi.org/10.1016/j.tra.2019.01.011

Shkarlet, S., Dubyna, M., Shtyrkhun, K., et al. (2020). Transformation of the Paradigm of the Economic Entities Development in Digital Economy. Wseas transactions on environment and development, 16, 413–422. https://doi.org/10.37394/232015.2020.16.41

Simonova, M., Lyachenkov, Y., Kostikova, E. (2021). Regional Labor Market: Supply and Demand in the Context of Digitalization. In: Ashmarina, S., Mantulenko, V. (editors). Lecture Notes in Networks and Systems. Springer, Cham. https://doi.org/10.1007/978- 3-030-47458-4_93.

Soete, L., Verspagen, B., & Ziesemer, T. H. W. (2021). Economic impact of public R&D: an international perspective. Industrial and Corporate Change, 31(1), 1–18. https://doi.org/10.1093/icc/dtab066

Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. The Quarterly Journal of Economics, 70(1), 65. https://doi.org/10.2307/1884513

Stoto, M. A., Woolverton, A., Kraemer, J., et al. (2022). COVID-19 data are messy: analytic methods for rigorous impact analyses with imperfect data. Globalization and Health, 18(1). https://doi.org/10.1186/s12992-021-00795-0

Suki, N. M., Sharif, A., Afshan, S., et al. (2020). Revisiting the Environmental Kuznets Curve in Malaysia: The role of globalization in sustainable environment. Journal of Cleaner Production, 264, 121669. https://doi.org/10.1016/j.jclepro.2020.121669

Sun, Y., Ak, A., Serener, B., et al. (2020). Natural resource abundance and financial development: A case study of emerging seven (E-7) economies. Resources Policy, 67, 101660. https://doi.org/10.1016/j.resourpol.2020.101660

Tran, B. X., Nguyen, H. T., Le, H. T., et al. (2020). Impact of COVID-19 on Economic Well-Being and Quality of Life of the Vietnamese During the National Social Distancing. Frontiers in Psychology, 11. https://doi.org/10.3389/fpsyg.2020.565153

Ulku, H. (2004). R&D, innovation, and economic growth: An empirical analysis. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=879010 (accessed 15 March, 2024)

UNCTAD. (2022). Gross domestic product - UNCTAD Handbook of Statistics 2022. UNCTAD.

Wang, Q., & Zhang, F. (2021). The effects of trade openness on decoupling carbon emissions from economic growth—Evidence from 182 countries. Journal of Cleaner Production, 279, 123838. https://doi.org/10.1016/j.jclepro.2020.123838

Yang, H. C., Syarifuddin, F., Chang, C. P., et al. (2021). The Impact of Exchange Rate Futures Fluctuations on Macroeconomy: Evidence from Ten Trading Market. Emerging Markets Finance and Trade, 58(8), 2300–2313. https://doi.org/10.1080/1540496x.2021.1976636

Yoruk, E., Radosevic, S., & Fischer, B. (2023). Technological profiles, upgrading and the dynamics of growth: Country-level patterns and trajectories across distinct stages of development. Research Policy, 52(8), 104847. https://doi.org/10.1016/j.respol.2023.104847

Zghidi, N., Sghaier, I. M., & Abida, Z. (2016). Does Economic Freedom Enhance the Impact of Foreign Direct Investment on Economic Growth in North African Countries? A Panel Data Analysis. African Development Review, 28(1), 64–74. https://doi.org/10.1111/1467-8268.12167

# Appendix

## Cointegration rank test results

| Bangladesh | | | | | Indonesia | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Unrestricted Cointegration Rank Test (Trace)** | | | | | **Unrestricted Cointegration Rank Test (Trace)** | | | | |
| **Hypothesized** | | **Trace** | **0.05** | **Prob.**** | **Hypothesized** | | **Trace** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** | **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1546 | 148.7109 | 95.7537 | 0.0000 | None * | 0.1396 | 128.3111 | 95.7537 | 0.0001 |
| At most 1 * | 0.0857 | 88.5761 | 69.8189 | 0.0008 | At most 1 * | 0.0927 | 74.6488 | 69.8189 | 0.0195 |
| At most 2 * | 0.0740 | 56.4928 | 47.8561 | 0.0063 | At most 2 | 0.0475 | 39.9226 | 47.8561 | 0.2253 |
| At most 3 | 0.0625 | 28.9865 | 29.7971 | 0.0618 | At most 3 | 0.0455 | 22.5576 | 29.7971 | 0.2685 |
| At most 4 | 0.0160 | 5.8949 | 15.4947 | 0.7079 | At most 4 | 0.0164 | 5.9432 | 15.4947 | 0.7022 |
| At most 5 | 0.0004 | 0.1380 | 3.8415 | 0.7102 | At most 5 | 0.0001 | 0.0365 | 3.8415 | 0.8485 |
| **Unrestricted Cointegration Rank Test (Max-eigenvalue)** | | | | | **Unrestricted Cointegration Rank Test (Max-eigenvalue)** | | | | |
| **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** | **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** | **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1546 | 60.1348 | 40.0776 | 0.0001 | None * | 0.1396 | 53.6623 | 40.0776 | 0.0008 |
| At most 1 | 0.0857 | 32.0833 | 33.8769 | 0.0806 | At most 1 * | 0.0927 | 34.7262 | 33.8769 | 0.0395 |
| At most 2 | 0.0740 | 27.5063 | 27.5843 | 0.0512 | At most 2 | 0.0475 | 17.3650 | 27.5843 | 0.5487 |
| At most 3 * | 0.0625 | 23.0917 | 21.1316 | 0.0262 | At most 3 | 0.0455 | 16.6144 | 21.1316 | 0.1910 |
| At most 4 | 0.0160 | 5.7568 | 14.2646 | 0.6446 | At most 4 | 0.0164 | 5.9067 | 14.2646 | 0.6252 |
| At most 5 | 0.0004 | 0.1380 | 3.8415 | 0.7102 | At most 5 | 0.0001 | 0.0365 | 3.8415 | 0.8485 |
| Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.05 level | | | | | Max-eigenvalue test indicates 2 cointegrating equation(s) at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | | * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) *p*-values | | | | | **MacKinnon-Haug-Michelis (1999) *p*-values | | | | |
| **Pakistan** | | | | | | **India** | | | |
| **Unrestricted Cointegration Rank Test (Trace)** | | | | | **Unrestricted Cointegration Rank Test (Trace)** | | | | |
| **Hypothesized** | | **Trace** | **0.05** | **Prob.**** | **Hypothesized** | | **Trace** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** | **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1570 | 134.9411 | 95.7537 | 0.0000 | None * | 0.10204 | 98.63542 | 95.75366 | 0.03119 |
| At most 1 * | 0.1072 | 73.8145 | 69.8189 | 0.0232 | At most 1 | 0.06419 | 60.10335 | 69.81889 | 0.23221 |
| At most 2 | 0.0465 | 33.2306 | 47.8561 | 0.5441 | At most 2 | 0.05241 | 36.35142 | 47.85613 | 0.37886 |
| At most 3 | 0.0289 | 16.1986 | 29.7971 | 0.6983 | At most 3 | 0.02694 | 17.07874 | 29.79707 | 0.63426 |
| At most 4 | 0.0135 | 5.6858 | 15.4947 | 0.7323 | At most 4 | 0.02011 | 7.30219 | 15.49471 | 0.54275 |
| At most 5 | 0.0023 | 0.8335 | 3.8415 | 0.3613 | At most 5 | 0.00008 | 0.02838 | 3.84147 | 0.86617 |

| Unrestricted Cointegration Rank Test (Max-eigenvalue) | | | | | Unrestricted Cointegration Rank Test (Max-eigenvalue) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** | **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** | **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1570 | 61.1265 | 40.0776 | 0.0001 | None | 0.10204 | 38.53207 | 40.07757 | 0.07388 |
| At most 1 * | 0.1072 | 40.5839 | 33.8769 | 0.0068 | At most 1 | 0.06419 | 23.75193 | 33.87687 | 0.47378 |
| At most 2 | 0.0465 | 17.0321 | 27.5843 | 0.5772 | At most 2 | 0.05241 | 19.27268 | 27.58434 | 0.39374 |
| At most 3 | 0.0289 | 10.5128 | 21.1316 | 0.6955 | At most 3 | 0.02694 | 9.77655 | 21.13162 | 0.76531 |
| At most 4 | 0.0135 | 4.8523 | 14.2646 | 0.7604 | At most 4 | 0.02011 | 7.27381 | 14.26460 | 0.45726 |
| At most 5 | 0.0023 | 0.8335 | 3.8415 | 0.3613 | At most 5 | 0.00008 | 0.02838 | 3.84147 | 0.86617 |
| Max-eigenvalue test indicates 2 cointegrating equation(s) at the 0.05 level | | | | | Max-eigenvalue test indicates no cointegration at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | | * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) *p*-values | | | | | **MacKinnon-Haug-Michelis (1999) *p*-values | | | | |
| **Malaysia** | | | | | **Philippines** | | | | |
| **Unrestricted Cointegration Rank Test (Trace)** | | | | | **Unrestricted Cointegration Rank Test (Trace)** | | | | |
| **Hypothesized** | | **Trace** | **0.05** | **Prob.**** | **Hypothesized** | | **Trace** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** | **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1336 | 122.0349 | 95.7537 | 0.0003 | None * | 0.1351 | 126.0221 | 95.7537 | 0.0001 |
| At most 1 * | 0.0797 | 70.8189 | 69.8189 | 0.0415 | At most 1 * | 0.0869 | 74.1938 | 69.8189 | 0.0214 |
| At most 2 | 0.0529 | 41.1834 | 47.8561 | 0.1829 | At most 2 | 0.0590 | 41.7308 | 47.8561 | 0.1664 |
| At most 3 | 0.0396 | 21.7922 | 29.7971 | 0.3102 | At most 3 | 0.0378 | 20.0155 | 29.7971 | 0.4218 |
| At most 4 | 0.0175 | 7.3690 | 15.4947 | 0.5351 | At most 4 | 0.0142 | 6.2711 | 15.4947 | 0.6635 |
| At most 5 | 0.0029 | 1.0502 | 3.8415 | 0.3055 | At most 5 | 0.0032 | 1.1530 | 3.8415 | 0.2829 |
| **Unrestricted Cointegration Rank Test (Max-eigenvalue)** | | | | | **Unrestricted Cointegration Rank Test (Max-eigenvalue)** | | | | |
| **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** | **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** | **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1336 | 51.2160 | 40.0776 | 0.0019 | None * | 0.1351 | 51.8283 | 40.0776 | 0.0016 |
| At most 1 | 0.0797 | 29.6355 | 33.8769 | 0.1477 | At most 1 | 0.0869 | 32.4630 | 33.8769 | 0.0730 |
| At most 2 | 0.0529 | 19.3911 | 27.5843 | 0.3849 | At most 2 | 0.0590 | 21.7153 | 27.5843 | 0.2353 |
| At most 3 | 0.0396 | 14.4233 | 21.1316 | 0.3313 | At most 3 | 0.0378 | 13.7444 | 21.1316 | 0.3864 |
| At most 4 | 0.0175 | 6.3188 | 14.2646 | 0.5727 | At most 4 | 0.0142 | 5.1181 | 14.2646 | 0.7268 |
| At most 5 | 0.0029 | 1.0502 | 3.8415 | 0.3055 | At most 5 | 0.0032 | 1.1530 | 3.8415 | 0.2829 |
| Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.05 level | | | | | Max-eigenvalue test indicates 1 cointegrating equation(s) at the 0.05 level | | | | |
| * denotes rejection of the hypothesis at the 0.05 level | | | | | * denotes rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) *p*-values | | | | | **MacKinnon-Haug-Michelis (1999) *p*-values | | | | |

| **Thailand** | | | | |
|---|---|---|---|---|
| **Unrestricted Cointegration Rank Test (Trace)** | | | | |
| **Hypothesized** | | **Trace** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1436 | 143.7491 | 95.7537 | 0.0000 |
| At most 1 * | 0.0971 | 88.2363 | 69.8189 | 0.0009 |
| At most 2 * | 0.0720 | 51.6578 | 47.8561 | 0.0210 |
| At most 3 | 0.0482 | 24.8955 | 29.7971 | 0.1652 |
| At most 4 | 0.0198 | 7.2091 | 15.4947 | 0.5535 |
| At most 5 | 0.0001 | 0.0319 | 3.8415 | 0.8582 |
| **Unrestricted Cointegration Rank Test (Max-eigenvalue)** | | | | |
| **Hypothesized** | | **Max-Eigen** | **0.05** | **Prob.**** |
| **No. of CE(s)** | **Eigenvalue** | **Statistic** | **Critical Value** | **Critical Value** |
| None * | 0.1436 | 55.5128 | 40.0776 | 0.0005 |
| At most 1 * | 0.0971 | 36.5785 | 33.8769 | 0.0232 |
| At most 2 | 0.0720 | 26.7623 | 27.5843 | 0.0634 |
| At most 3 | 0.0482 | 17.6865 | 21.1316 | 0.1420 |
| At most 4 | 0.0198 | 7.1771 | 14.2646 | 0.4684 |
| At most 5 | 0.0001 | 0.0319 | 3.8415 | 0.8582 |
| Max-eigenvalue test indicates 2 cointegrating equation(s) at the 0.05 level | | | | |
| *denote rejection of the hypothesis at the 0.05 level | | | | |
| **MacKinnon-Haug-Michelis (1999) *p*-values | | | | |