

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 combined 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 its 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, Charutawephonkoon 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 (Barguelli 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 UNCTAD¹ 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 balance², 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.

$$GDP = f(R\&D, NX, EXR, EMR, INF) \quad (1)$$

where, GDP= GDP growth rate, NX= trade balance, EXR= exchange rate, EMR= employment rate, INF= inflation rate, and ε = 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.

H₀₁: 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.

H₀ = 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.

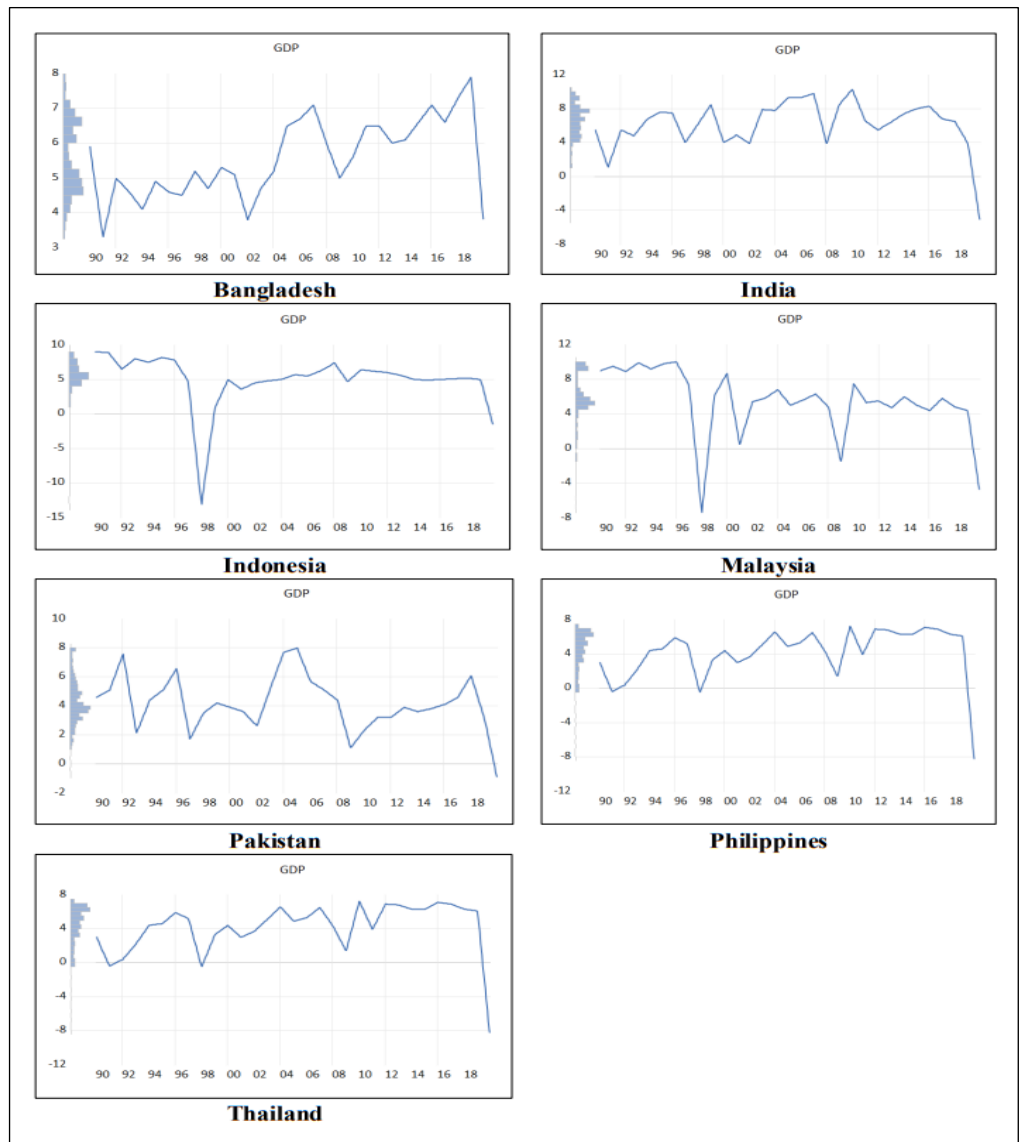


Figure 1. GDP growth rate trend analysis.

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				
Variables	ADF		Phillips-Perron Test		ADF		Phillips-Perron Test	
	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				
Variables	ADF		Phillips-Perron Test		ADF		Phillips-Perron Test	
	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				
Variables	ADF		Phillips-Perron Test		ADF		Phillips-Perron Test	
	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								
Variables	ADF		Phillips-Perron Test					
	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 first 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**
	<i>t</i> -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**
	<i>t</i> -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***
	<i>t</i> -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**
	<i>t</i> -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***
	<i>t</i> -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**
	<i>t</i> -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***
	<i>t</i> -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 β_0 and β_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 [37.1560]	0.9614 [31.1605]	0.8732 [13.8344]	0.8849 [30.6567]	0.8975 [38.7947]	0.9342 [29.9389]	0.9116 [32.9624]
D(R&D(-1))	0.0018 [3.4671]	1.04067 [0.5452]	0.9133 [3.3867]	0.1716 [5.1943]	0.3524 [0.9114]	0.1539 [0.1713]	2.3699 [3.9483]
D(NX(-1))	-0.0227 [-1.2264]	-0.0653 [-1.1173]	-0.0473 [-0.6990]	-0.0536 [-1.4017]	0.0047 [0.2545]	-0.0099 [-0.2821]	0.0298 [1.1424]
D(EXR(-1))	0.0025 [0.2042]	0.0425 [1.9806]	0.0001 [0.4626]	0.0562 [0.0868]	-0.0056 [-0.6442]	0.0042 [0.1959]	-0.0325 [-1.4036]
D(EMR(-1))	0.0534 [1.0661]	-0.0314 [-0.3536]	-0.1121 [-0.7862]	0.7068 [2.6219]	0.0411 [0.5089]	0.0871 [0.7121]	0.0439 [0.3297]
D(INF(-1))	0.0014 [0.1586]	0.0182 [0.7392]	0.0021 [0.1065]	0.0482 [0.6066]	-0.0166 [-0.9636]	0.0108 [0.3915]	-0.0005 [-0.0099]
C	0.0005 [0.1943]	-0.0094 [-1.4657]	0.0059 [0.5989]	0.0122 [1.1737]	0.0006 [0.1203]	0.0031 [0.5024]	0.0104 [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.

Hypothesis:	Indonesia		Malaysia		Philippines		Thailand		Bangladesh		India		Pakistan	
	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 H ₀ : 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 Root 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.

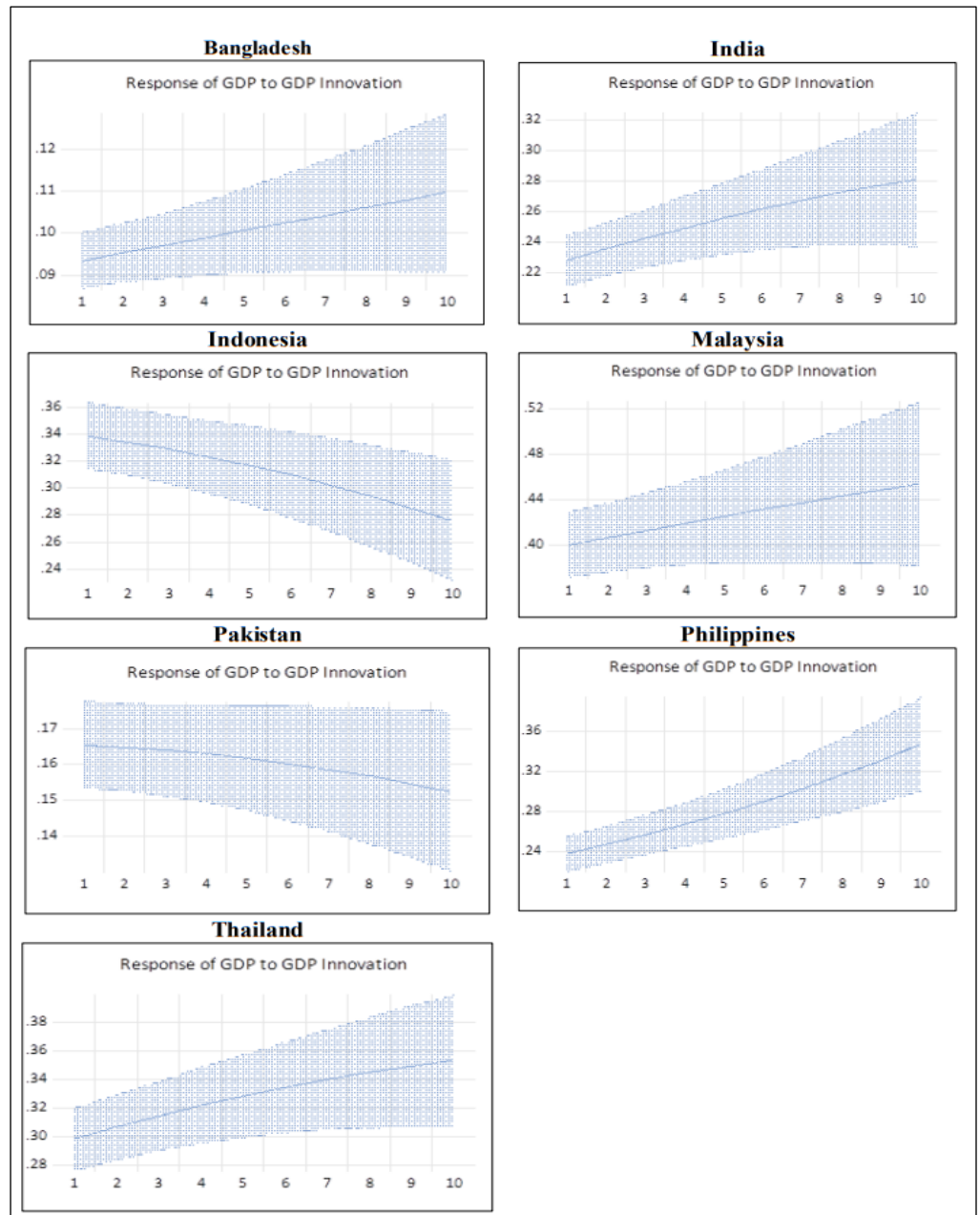


Figure 2. Sensitivity analysis.

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 GDP 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'.

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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) <i>p</i> -values					**MacKinnon-Haug-Michelis (1999) <i>p</i> -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) <i>p</i> -values					**MacKinnon-Haug-Michelis (1999) <i>p</i> -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) <i>p</i> -values					**MacKinnon-Haug-Michelis (1999) <i>p</i> -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