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Innovation and Economic Growth in the Top Five Southeast Asian Economies: A Decomposition Analysis

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Abstract

Innovation has the potential to act as a double-edged sword in impacting economic growth. While it serves as a powerful driver of economic advancement, it also carries risks alongside its benefits. Recognizing this duality, our study aims to fill the identified gap and add comprehensiveness to the literature by assessing the individual impact of innovation indicators on economic growth in the top five Southeast Asian (SEA) countries based on Gross Domestic Product (GDP): Indonesia, Thailand, Singapore, Malaysia, and Vietnam. The innovation aspect comprises 21 indicators from the Global Innovation Index (GII), grouped into seven categories: institution, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, and creative outputs. Both panel analysis and country-specific assessments consistently conclude that innovation significantly influences economic growth. However, delving into the categorized indicators reveals intriguing insights. While all the indicators demonstrate a notable impact, most of them are found to hinder rather than foster economic growth. This compelling empirical evidence underscores that innovation in the selected countries has yet to be optimized, highlighting the urgent need to implement innovation-friendly policies, including removing innovation barriers, targeting investment in key sectors, and fostering education and skills development. This holistic approach aims to cultivate an environment conducive to innovation, thereby solidifying innovation's role as one of the primary drivers of economic growth.



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1. Introduction

Innovation catalyzes economic growth by fostering productivity enhancements, technological advancements, and market expansion [1–4]. Through the development of new products, services, and processes, innovation drives efficiency gains, increasing output and

contributing to overall economic expansion [5–8]. Furthermore, innovation stimulates entrepreneurship and creates new business opportunities. As industries evolve and adapt to innovative ideas, they become more competitive globally, attracting investments and spurring further growth [9–13].

The relationships between innovation and economic growth also have the potential for negative impacts, which can emerge when innovation leads to significant disruptions in labor markets, causing job displacement and widening income inequality. While technological advancements may streamline processes and boost productivity, they can also render certain skills obsolete, resulting in unemployment for workers who need more expertise [14, 15]. Moreover, the initial costs associated with innovation, such as research and development expenditures, can strain resources and hinder short-term growth, particularly for smaller firms with limited financial capabilities [16–20]. Additionally, if innovation primarily benefits a select few, it may exacerbate disparities between regions or socioeconomic groups, undermining social cohesion and impeding overall economic progress [21–23].

One prominent theory that serves as a foundation for understanding the relationship between innovation and economic growth is the 'Schumpeterian Growth Theory.' This theory suggests that innovation is central to economic growth by creating new products, processes, and technologies, leading to increased productivity, higher profits, and overall economic advancement [24]. In the theory, the concept of 'creative destruction' refers to the process whereby innovations disrupt existing industries, products, and technologies. This constant churn of innovation replaces older, less efficient methods with newer, more productive ones, thereby driving economic progress [25, 26].

The latest report reveals compelling insights into the innovation landscape of the Southeast Asian (SEA) region, highlighting significant advancements and trends among the five selected countries. Singapore emerges as a frontrunner in innovation, securing the 5th position globally and leading the Asian region in the prestigious Global Innovation Index (GII). Following closely behind are Malaysia (36th), Thailand (43rd), Vietnam (46th), and Indonesia (61st), each showcasing varying degrees of innovation prowess. Of particular note are Vietnam and Indonesia, which are recognized as standout performers in the past decade. Vietnam's remarkable ascent from 76th in 2013 to 46th in 2023 underscores its commitment to fostering innovation and technological progress. Similarly, Indonesia's impressive climb from 85th to 61st during the same period reflects its concerted efforts to bolster its innovation ecosystem [27]. These achievements underscore the region's growing significance on the global innovation stage, positioning SEA as a potential dynamic hub for creativity, entrepreneurship, and technological advancement.

Despite boasting vibrant economies with burgeoning tech sectors, challenges related to innovation in SEA countries often stem from problems such as limited access to funding for research and development, inadequate infrastructure, and a shortage of skilled labor [28, 29]. Moreover, most SEA nations face difficulties in allocating adequate resources to nurture innovation [30–32]. Furthermore, regulatory barriers and bureaucratic hurdles often impede entrepreneurial initiatives, thereby slowing the pace of innovation [33–35]. Additionally, a significant challenge lies in bridging the gap between urban and rural areas regarding access to technology and innovation opportunities, exacerbating inequalities within these societies [36, 37]. These issues, related to the innovation environment, can greatly impact a country's economic growth performance.

Previous studies, based on samples from 58 countries, provided empirical evidence that countries with higher levels of innovation also tended to experience higher economic growth [38]. Another study similarly concluded that economic growth correlated with advancements in the innovation sector [39]. The impact of innovation on economic growth was also examined in the regions of Europe, with findings suggesting a strong association between innovation and economic growth [40].

Furthermore, empirical analysis for CEE countries provided evidence of a positive relationship between economic growth and innovation [41]. Likewise, an examination of the relationship between innovation and economic growth in 19 European countries revealed both unidirectional and bidirectional causality [42]. The summary summarizes relevant literature documenting the impact of innovation on economic growth, and despite unambiguous regarding how ongoing innovation has improved the economy, the aspects of technological change are real in making innovation one of the main drivers of economic progress [43].

Although prior studies in SEA have extensively explored the relationship between innovation and economic growth [44–47], there remains a notable gap in research focusing on assessing this linkage using the Global Innovation Index (GII) as a proxy for innovation. Specifically, there is a lack of studies that analyze each of the individual group indicators separately. Some studies, such as that by Sulaiman et al. [48], utilized trademark applications and scientific and technical journal articles as indicators of innovation. Meanwhile, Lv et al. [49] focused on a single R&D input as an indicator of innovation, and Sultanuzzaman et al. [50] used fixed telephone subscriptions as a proxy for technological innovation.

Table 1. Variable synopsis.

Variable	Symbol	Description	Units (Sources)	Variable's detail
Dependent	GDP	Gross domestic product	Constant LCU (WDI)	The sum of gross value added by all resident producers in the economy.
Control	K	Gross fixed capital formation	Constant LCU (WDI)	The sum of gross value added by land improvements; plant, machinery, and equipment purchases; and the construction of public goods.
	L	Labor force	Person (WDI)	Comprises people ages 15 and older who supply labor for producing goods and services during a specified period.
Independent	GII	Global innovation index	Score between 1-100 (WIPO)	Refers to a composite index that considers factors such as the institution, human capital and research, infrastructure, market sophistication, business sophistication, knowledge, technology, and creative outputs.
	INS	Institution		Refers to indicators such as political, regulatory, and business environment.
	HCR	Human capital and research		Refers to indicators such as education, research, and development.
	IFR	Infrastructure		Refers to indicators such as information and communication technologies, general infrastructure, and ecological sustainability.
	MKS	Market sophistication		Refers to indicators such as credit, investment, trade, competition, and market scale.
	BSS	Business sophistication		Refers to indicators such as knowledge workers, innovation linkages, and knowledge absorption.
	KTO	Knowledge and technology outputs		Refers to indicators such as knowledge creation and impact, and knowledge diffusion.
	CTO	Creative outputs		Refers to indicators such as intangible assets, creative goods and services, and online creativity.



Figure 1. Conceptual framework of the study.

Given this existing research gap in SEA economic growth literature concerning the role of innovation, this study sets itself apart by employing a decomposition analysis. This approach encompasses 21 indicators grouped into seven categories of the GII to assess their individual impacts on economic growth—an aspect not previously investigated in selected countries of SEA studies. The novelty of this study lies in its ability to present more comprehensive empirical evidence concerning the

relationship between innovation and economic growth in the top five SEA nations.

2. Materials and Methods

2.1. Data and Variable

This study utilized yearly data from 2011 to 2022. The justification for the chosen period lies in the availability of data, as the farthest back available data for Global Innovation Index (GII) indicators is from 2011, while the most recent data for all variables utilized extends to 2022. Additionally, given the relatively short duration of the chosen period, the study converted annual data to semi-annual intervals to enhance the robustness and reliability of regression estimates, effectively doubling the number of observations. The sample objective of this study is the top five countries based on gross domestic product (GDP) for the year 2022, according to the International Monetary Fund (IMF) [51]: Indonesia, Thailand, Singapore, Malaysia, and Vietnam.

Specifically, the data for economic growth is proxied by GDP; capital data is represented by gross fixed capital formation (GFCF); labor data is depicted by the labor force (LF); and innovation data is proxied by the Global Innovation Index (GII). GDP, GFCF, and LF data were sourced from the World Bank's World Development

Table 2. Descriptive statistics.

Variable	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
lnGDP	31.46	29.94	37.00	26.61	4.16	0.25	1.27	16.24
lnK	30.17	28.52	35.84	25.27	4.29	0.27	1.26	16.52
lnL	17.12	17.51	18.74	14.94	1.25	-0.52	2.10	9.48
lnGII	3.69	3.64	4.15	3.28	0.24	0.37	2.27	5.32
lnINS	4.12	4.09	4.56	3.23	0.29	-0.24	3.17	1.29
lnHCR	3.58	3.45	4.31	3.04	0.37	0.47	2.09	8.64
lnIFR	3.76	3.76	4.24	3.20	0.25	0.02	2.64	0.67
lnMKS	3.99	4.00	4.37	3.47	0.21	-0.04	2.74	0.37
lnBSS	3.64	3.57	4.37	2.86	0.36	0.18	2.40	2.47
lnKTO	3.45	3.45	4.17	2.87	0.31	-0.02	2.59	0.86
lnCTO	3.52	3.55	3.82	2.86	0.21	-1.20	4.47	39.82

Indicators (WDI) [52], and GII data was obtained from the World Intellectual Property Organization (WIPO) [53]. Details about the variables used in this study are presented in Table 1.

2.2. Econometric Model

The endogenous growth model is employed to examine the profound impact of innovation on economic growth. Distinguishing itself by incorporating a pragmatic Cobb-Douglas production function and acknowledging the significant contributions of capital and labor to production, the model further integrates internal factors within an economy, rather than relying solely on external shocks or exogenous variables. It emphasizes the role of technological progress, human capital accumulation, and knowledge spillovers. Unlike earlier models such as the Solow-Swan framework, endogenous growth theory suggests that increasing returns to scale can exist in certain sectors, leading to self-sustaining growth dynamics. As shown in Figure 1, innovation is seen as a crucial driver of economic growth under this framework [54–56].

This study examines how GDP is influenced by three key factors: capital, labor, and innovation. By examining the interplay among these elements, this study aims to unravel the nuanced mechanisms through which they shape economic growth. From the traditional inputs of capital and labor to the transformative power of innovation, the study seeks to comprehend the dynamic forces driving economic growth. The functional relationship is mathematically expressed in Equation 1.

$$GDP = f(K, L, INV) \tag{1}$$

where *GDP* represents gross domestic product, *K* refers to gross fixed capital formation, *L* represents labor force, and *INV* stands for global innovation index and its indicators.

Consequently, the relationship between variables for the econometric model is depicted in Equations 2-9.

$$GDP_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 L_{it} + \beta_3 \begin{bmatrix} GII_{it} \\ INS_{it} \\ HCR_{it} \\ IFR_{it} \\ MKS_{it} \\ BSS_{it} \\ KTO_{it} \\ CTO_{it} \end{bmatrix} + \varepsilon_t \tag{2-9}$$

Furthermore, Equations 2-9 were transformed into natural logarithmic (ln) form so that the coefficients obtained from regression analysis can be interpreted as percentage changes rather than absolute changes, as expressed in Equations 10-17.

$$\ln GDP_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \begin{bmatrix} \ln GII_{it} \\ \ln INS_{it} \\ \ln HCR_{it} \\ \ln IFR_{it} \\ \ln MKS_{it} \\ \ln BSS_{it} \\ \ln KTO_{it} \\ \ln CTO_{it} \end{bmatrix} + \varepsilon_{it} \tag{10-17}$$

Here, *i* represents the country, *t* represents the time of the study period, β_0 signifies the intercept, β_1 - β_3 represent the coefficients, and ε is the error term.

2.3. Methods

2.3.1. Panel Data Regression

Panel data regression is a method used to analyze data that involves both cross-sectional and time-series data. In other words, it deals with data collected from multiple entities (cross-sectional units of countries) over multiple periods. The key feature of panel data is to examine both within-unit variations over time and between-unit variations across different entities. This type of data structure is valuable because it captures individual heterogeneity and temporal dynamics simultaneously [57, 58].

There are three common types of panel data regression models: the Common Effect Model (CEM), the Fixed Effect Model (FEM), and the Random Effect Model (REM). CEM is

Table 3. Results of Chow and Hausman test.

Panel Model	Chow Test		Hausman Test		Conclusion
	Statistic	Prob.	Statistic	Prob.	
$GDP = f(K, L, GII)$	70.5835*	0.0000	89.6619*	0.0000	Best model: FEM
$GDP = f(K, L, INS)$	85.5728*	0.0000	116.487*	0.0000	Best model: FEM
$GDP = f(K, L, HCR)$	81.7211*	0.0000	109.253*	0.0000	Best model: FEM
$GDP = f(K, L, IFR)$	81.5004*	0.0000	108.832*	0.0000	Best model: FEM
$GDP = f(K, L, MKS)$	75.6375*	0.0000	98.3251*	0.0000	Best model: FEM
$GDP = f(K, L, BSS)$	83.6422*	0.0000	112.866*	0.0000	Best model: FEM
$GDP = f(K, L, KTO)$	81.1415*	0.0000	108.206*	0.0000	Best model: FEM
$GDP = f(K, L, CTO)$	85.3825*	0.0000	116.078*	0.0000	Best model: FEM

Note: Significant at * (1%).

Table 4. Results of panel data regression for SEA composite GII.

Dependent: GDP		Model 1		
Variable		CEM	FEM	REM
C		5.4694 (7.0441)*	-3.5136 (2.0739)**	5.4694 (9.2881)*
K	Coeff.	0.9506 (391.66)*	0.7059 (21.59)*	0.9506 (516.44)*
L	(t-stat.)	-0.0342 (1.4406)	0.8787 (7.8434)*	-0.0342 (1.8995)***
GII		-0.5708 (5.1781)*	-0.3704 (3.6736)*	-0.5708 (6.8277)*
Adj. R ²		0.9998	0.9999	0.9998
F-stat. Prob.		0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

a standard Ordinary Least Squares (OLS) regression, FEM is preferred when there is a concern about time-invariant individual-specific effects, while REM is suitable when such effects are assumed to be uncorrelated with the independent variables [59, 60]. Subsequently, the Chow and Hausman tests are conducted to choose the best model from the three and serve as the main basis for interpreting the results of the panel model.

2.3.2. Robust Least Squares

In traditional OLS regression, the model parameters are estimated by minimizing the sum of squared differences between the observed and predicted values. However, this approach can be highly affected by outliers. RLS aims to provide more reliable parameter estimates by using alternative criteria for optimization, minimizing the sum of the Huber loss for all data points. This method helps ensure that the estimated regression parameters are less influenced by extreme observations, leading to more reliable and accurate models [61, 62].

3. Results and Discussion

3.1. Descriptive Statistics

The descriptive statistics provide insights into various variables within the utilized dataset. As depicted in Table 2, lnGDP and lnK exhibit relatively symmetric distributions with moderate variability and slightly

positive skewness. lnL displays a symmetric distribution with low variability and negative skewness, suggesting left skew and heavier tails. lnGII, lnINS, and lnBSS show symmetric distributions with low variability and varying degrees of skewness and kurtosis, indicating departures from normality. lnHCR, lnIFR, lnMKS, lnKTO, and lnCTO exhibit distributions with characteristics similar to other variables, but with distinct skewness and kurtosis. Notably, the lnCTO variable demonstrates a significant departure from normality according to the Jarque-Bera test.

3.2. Econometric Results

3.2.1. Top Five Southeast Asian Economies

The panel model is carefully assessed to determine the best fit. As indicated in Table 3, both Chow and Hausman tests yield statistically significant values at the 1% level. These testing results confirm that FEM is the most appropriate model among all panel models employed in this study.

The impact of innovation on economic growth is hypothesized to be positive. Innovation is expected to drive productivity gains and improve living standards, thereby potentially boosting economic growth. However, as shown in Table 4, the GII variable yields results that contradict these expectations, showing a negative coefficient, indicating that a 1.0% increase in GII can lead to a 0.3704% decrease in economic growth. This empirical evidence underscores that while innovation plays a critical role in shaping the economic growth of the top five SEA countries, the environment for innovation remains suboptimal.

Delving into the GII indicators' findings in Table 5, it becomes evident that most of the key indicators also demonstrate a detrimental effect on economic growth in the Top five SEA countries, with the exception of the INS indicator, which exhibits a positive correlation. Specifically, a 1.0% rise in the HCR, MKS, BSS, KTO, and CTO indicators is associated with a decrease in economic growth by 0.0413%, 0.0265%, 0.1128%, 0.0539%, and

Table 5. Results of FEM panel data regression for SEA GII indicators.

<i>Dependent: GDP</i>							
Variable	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
C	-6.7361 (7.6469)	-5.5824 (5.3384)*	-7.0338 (5.0079)*	-6.6868 (7.0442)*	-3.2579 (1.7233)***	-6.4666 (7.1683)*	-4.0041 (2.4469)*
K	0.6469 (54.175)*	0.6858 (62.321)*	0.7204 (33.456)*	0.6837 (64.423)*	0.6398 (19.521)*	0.6774 (56.829)*	0.6459 (20.365)*
L	1.0779 (18.763)*	0.9639 (13.316)*	0.9841 (11.048)*	1.0296 (15.447)*	0.9246 (8.3071)*	1.0326 (15.735)*	0.9553 (9.2118)*
INS	0.0549 (3.5426)*						
HCR		-0.0413 (2.5036)**					
IFR			-0.0234 (0.8592)				
MKS				-0.0265 (2.0391)**			
BSS					-0.1128 (3.0967)*		
KTO						-0.0539 (3.6992)*	
CTO							-0.1066 (3.5568)*
Adj. R ²	0.9999	0.9999	0.9998	0.9998	0.9998	0.9999	0.9998
F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

Table 6. Results of RLS for top five SEA countries composite GII.

<i>Dependent: GDP</i>						
Country	Variable	Model 9	Model 10	Model 11	Model 12	Model 13
	C	3.3662 (0.9854)	24.6069 (3.2851)*	2.7129 (0.4139)	6.1256 (7.5906)*	-0.0725 (0.0273)
	K	1.0066 (8.4475)*	1.1533 (20.889)*	0.4431 (2.0713)**	0.1959 (7.5459)*	0.7605 (41.545)*
	L	-0.1023 (0.2582)	-1.6235 (4.4988)*	1.1769 (2.4126)**	1.1443 (21.078)*	0.5888 (3.2508)*
Indonesia	GII	-0.1661 (2.6284)*				
Thailand	GII		0.2355 (2.1845)**			
Singapore	GII			-1.1944 (2.2558)**		
Malaysia	GII				-0.6369 (8.9384)*	
Vietnam	GII					-0.2686 (5.3724)*
	Adj. R ²	0.9957	0.9823	0.8329	0.9979	0.9988
	F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

0.1066% respectively. Conversely, a 1.0% increase in the INS indicator corresponds to a decrease in economic growth by 0.0549%.

3.2.2. Indonesia

Similar to the panel data results, the GII variable in Indonesia also exhibits a negative impact on economic

growth. As depicted in Table 6, the results indicate that a 1.0% increase in GII can decrease economic growth by 0.1661%. This indication may be triggered by the characteristic of innovation, which tends to involve reallocating resources away from existing industries or technologies toward new ones. This reallocation process could lead to economic disruptions or displacements in certain sectors of Indonesia that still operate in a

Table 7. Results of RLS for Indonesia GII indicators.

<i>Dependent: GDP</i>							
Variable	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20
C	-2.1031 (1.7193)***	-7.1319 (3.8276)*	-2.9414 (3.0928)*	-4.4878 (3.0843)*	1.8862 (1.2569)	0.0498 (0.0145)	4.6382 (1.4424)
K	0.8919 (20.561)*	0.9081 (11.245)*	1.4141 (20.362)*	0.9488 (13.412)*	0.8624 (15.658)*	0.9331 (8.3507)*	0.9811 (9.9563)*
L	0.3716 (2.5806)*	0.5981 (2.5993)*	-0.5304 (3.4171)*	0.4159 (2.0801)**	0.2333 (1.3116)	0.1954 (0.5056)	-0.1428 (0.4099)
INS	0.0411 (5.7311)*						
HCR		0.1197 (3.3658)*					
IFR			-0.2182 (8.848)*				
MKS				-0.0848 (3.8795)*			
BSS					-0.0659 (5.9561)*		
KTO						-0.0588 (1.6734)***	
CTO							-0.0504 (3.3247)
Adj. R ²	0.9991	0.9365	0.9443	0.9475	0.9983	0.9226	0.9964
F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

traditional manner, potentially slowing overall economic growth.

In terms of specific GII indicators, [Table 7](#) reveals that four indicators exert a negative impact (IFR, MKS, BSS, and KTO), and two indicators exhibit a positive impact (INS and HCR), while one indicator does not have a significant impact (CTO). A 1.0% increase in the indicators of IFR, MKS, BSS, and KTO can decrease Indonesia's economic growth by 0.2182%, 0.0848%, 0.0659%, and 0.0588%, respectively. Meanwhile, a 1.0% increase in the indicators of INS and HCR can increase Indonesia's economic growth by 0.0411% and 0.1197%, respectively. These decomposing results support the findings of the negative impact of GII on Indonesia's economic growth.

3.2.3. Thailand

In contrast to panel estimation results, Thailand's GII exhibits a positive impact on economic growth. The findings, as shown in [Table 6](#), suggest that a 1.0% increase in GII can contribute to boosting economic growth by 0.2355%. This signifies that Thailand's innovation environment is already at a state where it can be one of the factors driving up the country's economic growth level. The level of innovation in the country can lead to the development of new technologies, processes, and products, which can increase the efficiency and output of businesses, thereby fostering economic activity.

Furthermore, Thailand's GII indicators reinforce the positive impact of the innovation environment in the country. Among these indicators, only the IFR and BSS exhibit negative coefficients, while four others (INS, HCR, MKS, and CTO) demonstrate a positive influence on economic growth. Specifically, [Table 8](#) shows that a 1.0% increase in the IFR and BSS indicators can lead to a decrease in Thailand's economic growth by 0.0942% and 0.1663%, respectively. Conversely, a 1.0% increase in the INS, HCR, MKS, and CTO indicators can boost Thailand's economic growth by 0.0833%, 0.0644%, 0.0648%, and 0.1424%, respectively.

3.2.4. Singapore

Singapore is considered one of the countries that have a high level of innovation environment, and it's one of the primary drivers of the country's economy. However, the estimation results contradict this notion. As depicted in [Table 6](#), the GII variable produces a negative coefficient toward economic growth. Specifically, a 1.0% increase in GII can lead to a decrease in the country's economic growth by 1.1944%. These results perhaps indicate that despite the main composition of the innovation itself being already at a strong level, the other sectors that support innovation are still considered detrimental to fostering the country's economic growth.

Diving into Singapore's GII indicators, the findings in [Table 9](#) show that three indicators (INS, HCR, and BSS)

Table 8. Results of RLS for Thailand GII indicators.

<i>Dependent: GDP</i>							
Variable	Model 21	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27
C	32.8209 (5.7529)*	32.8068 (11.662)*	41.7657 (9.4381)*	38.9249 (8.4759)*	10.6764 (2.0291)**	31.5368 (4.0831)*	-4.1918 (1.4211)
K	1.0494 (24.695)*	1.1101 (59.103)*	1.2191 (19.215)*	1.0751 (34.231)	0.9966 (34.865)*	1.1127 (18.159)*	1.4094 (46.413)*
L	-1.8939 (6.5581)*	-1.9857 (14.351)*	-2.6419 (10.773)	-2.2798 (9.8253)*	-0.4899 (1.5478)	-1.8966 (4.9265)*	-0.3753 (2.9416)*
INS	0.0833 (3.1391)*						
HCR		0.0644 (5.7907)*					
IFR			-0.0942 (3.4238)*				
MKS				0.0648 (2.3976)**			
BSS					-0.1663 (7.0872)*		
KTO						-0.0404 (0.9289)	
CTO							0.1424 (10.921)*
Adj. R ²	0.9903	0.8892	0.9947	0.8731	0.9947	0.9796	0.8881
F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

Table 9. Results of RLS for Singapore GII indicators.

<i>Dependent: GDP</i>							
Variable	Model 28	Model 29	Model 30	Model 31	Model 32	Model 33	Model 34
C	-4.5249 (0.8918)	-7.8257 (2.5256)**	-33.2449 (19.606)*	1.3305 (0.4217)	-50.8822 (6.0513)*	-7.0489 (1.3545)	1.0594 (0.2187)
K	0.1822 (0.7799)	-0.0499 (0.4032)	0.9665 (13.605)*	-0.1292 (1.2061)	0.8329 (5.9227)*	0.2394 (0.9969)	1.7433 (7.2755)*
L	0.4748 (0.6007)	2.3179 (9.3134)*	2.5927 (21.714)*	2.0699 (11.861)*	3.3432 (6.2486)*	1.8605 (3.9331)*	-1.0085 (2.1305)**
INS	4.3071 (2.1256)**						
HCR		0.2471 (2.3373)**					
IFR			-0.8532 (17.316)*				
MKS				-0.5475 (3.3427)*			
BSS					1.4811 (5.7932)*		
KTO						-0.0535 (0.3367)	
CTO							-0.9321 (3.3082)*
Adj. R ²	0.8289	0.9421	0.9864	0.6711	0.9386	0.8128	0.8789
F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

exert a positive impact, while three indicators (IFR, MKS, and CTO) exhibit a negative impact on economic growth. Additionally, one indicator (KTO) is found to have no significant impact. Specifically, a 1.0% increase in INS, HCR, and BSS indicators can boost Singapore's economic

growth by 4.3071%, 0.2471%, and 1.4811% respectively. Conversely, a 1.0% increase in IFR, MKS, and CTO indicators can reduce Singapore's economic growth by 0.8532%, 0.5475%, and 0.0535% respectively.

Table 10. Results of RLS for Malaysia GII indicators.

<i>Dependent: GDP</i>							
Variable	Model 35	Model 36	Model 37	Model 38	Model 39	Model 40	Model 41
C	-6.3347 (9.7289)	-11.2451 (26.799)*	-12.3581 (10.873)*	-10.1546 (49.589)*	-8.1957 (17.944)*	-12.1297 (28.243)*	-1.4708 (2.7945)*
K	0.2805 (9.1826)	0.4028 (21.551)*	0.4428 (10.551)*	0.2571 (36.782)*	0.3648 (43.921)*	0.4046 (20.037)*	0.3171 (16.189)*
L	1.7218 (36.533)*	1.7353 (67.041)*	1.7408 (56.595)*	1.8749 (145.49)*	1.5999 (74.958)*	1.7543 (57.201)*	1.3043 (33.609)*
INS	-0.4094 (4.8722)*						
HCR		-0.0764 (2.1818)					
IFR			-0.0834 (2.1619)**				
MKS				0.0415 (3.9742)*			
BSS					-0.0251 (2.2497)**		
KTO						0.0663 (2.5328)**	
CTO							-0.1813 (9.0827)*
Adj. R ²	0.9932	0.9971	0.9965	0.9997	0.9602	0.9971	0.9979
F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

3.2.5. Malaysia

As indicated in Table 6, Malaysia’s GII also mirrors the panel findings by demonstrating a negative impact on economic growth. The estimations reveal that a 1.0% increase in GII could diminish economic growth by 0.6369%. Similar to Indonesia, these results might be related to the reallocation of resources away from existing industries or technologies toward new ones. However, the reallocation process may not be optimized yet, leading to economic disruptions that slow overall economic growth. Inefficient allocation of resources, coupled with inadequate infrastructure and regulatory frameworks, could impede the smooth transition to innovative sectors.

The composite GII evidence, supported by the estimation results of its indicators as shown in Table 10, unveils a nuanced picture of Malaysia’s innovation dynamics. Among the seven indicators examined, it becomes evident that five—namely INS, HCR, IFR, BSS, and CTO—exert a negative impact on Malaysia’s economic growth. Conversely, the MKS and KTO indicators showcase a positive impact. Specifically, a 1.0% increase in INS, HCR, IFR, BSS, and CTO indicators can lead to a decrease in Malaysia’s economic growth by 0.4094%, 0.0764%, 0.0834%, 0.0251%, and 0.1813%, respectively. In contrast, a 1.0% increase in the MKS and CTO indicators can boost Malaysia’s economic growth by 0.0415% and 0.0663%, respectively.

3.2.6. Vietnam

In line with Indonesia, Singapore, and Malaysia estimation results, Vietnam’s GII also exerts the same negative impact on economic growth. As shown in Table 6, a 1.0% increase in GII can lead to a decrease in economic growth by 0.2686%. This indication provides similar trigger conditions as Indonesia and Malaysia, where the innovation sector is still detrimental to the country’s economic growth and remains under-optimized. Innovation often involves upfront costs and risks before translating into economic benefits. In the short term, the costs of innovation may outweigh the benefits, leading to a negative relationship with economic growth.

Table 11 GII indicators also align with the composite findings, wherein only one indicator (BSS) has a positive impact on economic growth, while six other indicators (INS, HCR, IFR, MKS, KTO, and CTO) all produce negative impacts. Specifically, a 1.0% increase in the BSS indicator can positively impact Vietnam’s economic growth by 0.0637%. Meanwhile, a 1.0% increase in INS, HCR, IFR, MKS, KTO, and CTO can reduce Vietnam’s economic growth by 0.1045%, 0.1164%, 0.1322%, 0.0752%, 0.0879%, and 0.1235% respectively.

3.3. Discussion

Contrary to the prevailing theoretical expectation of a positive impact, the empirical evidence from the GII

Table 11. Results of RLS for Vietnam GII Indicators.

<i>Dependent: GDP</i>							
Variable	Model 42	Model 43	Model 44	Model 45	Model 46	Model 47	Model 48
C	4.5016 (1.3162)	4.9228 (2.0548)**	-4.6112 (2.1991)**	4.5486 (1.2957)	0.9388 (0.5788)	-1.3849 (0.6387)	6.6392 (1.7846)***
K	0.8114 (25.164)*	0.7769 (45.698)*	0.8013 (48.361)*	0.7884 (31.077)*	0.8011 (78.414)*	0.7259 (51.973)*	0.7579 (30.153)*
L	0.2014 (0.8416)	0.2437 (1.4949)	0.7357 (5.3558)*	0.2369 (0.9898)	0.3853 (3.6501)*	0.6932 (4.6457)*	0.1871 (0.7663)
INS	-0.1045 (2.4131)*						
HCR		-0.1164 (5.2764)*					
IFR	Coeff. (t-stat.)		-0.1322 (5.7299)*				
MKS				-0.0752 (2.9234)*			
BSS					0.0637 (4.5464)*		
KTO						-0.0879 (5.8499)*	
CTO							-0.1235 (2.5147)**
Adj. R ²	0.9975	0.9988	0.9991	0.9975	0.9581	0.9561	0.9973
F-stat. Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Significant at * (1%), ** (5%), and *** (10%).

reveals a paradoxical negative coefficient, suggesting that an increase in innovation might correspond to a decrease in economic growth in the top five SEA countries. This discrepancy underscores the complexity of the innovation-economic growth nexus and emphasizes the importance of examining the specific components and institutional frameworks surrounding innovation. As depicted in Table 12, while institutions positively correlate with economic growth, other key indicators, such as human capital and research, market sophistication, business sophistication, and knowledge and technology outputs, demonstrate adverse effects. The panel findings are further supported by each of the country's results, indicating that only Thailand's GII has a positive relationship with economic growth, while Indonesia, Singapore, Malaysia, and Vietnam all exhibit a negative impact. These findings call for a nuanced understanding of the innovation ecosystem in these countries, suggesting potential gaps in policy support that may hinder the transformative power of innovation on economic development [63–66].

Diving into the decomposed results of the GII indicators in each country, Indonesia's findings reveal that only two out of seven indicators have a positive impact on economic growth: institution and human capital and research. However, indicators such as infrastructure, market and business sophistication, and knowledge and technology outputs still exert a detrimental effect on the country's economy. Addressing these challenges through

targeted policy interventions, investments in critical infrastructure, education and skills development, and fostering an enabling business environment can help unlock Indonesia's innovation potential and drive sustainable economic growth [67–73].

Meanwhile, Thailand's assessment of GII indicators indicates that four out of seven factors positively impact economic growth: institutions, human capital and research, market sophistication, and creative outputs. This suggests that Thailand has made notable strides in cultivating an innovation ecosystem that not only fosters robust institutional frameworks and invests in human capital and research but also demonstrates a keen understanding of market dynamics and the ability to generate creative solutions. These positive indicators underscore Thailand's potential to leverage innovation as a cornerstone for driving sustained economic growth and remaining competitive on the global stage [74–76].

A notable discovery emerges in Singapore, where the innovation sector is widely perceived as a cornerstone of the country's economic engine. However, Singapore's GII indicators reveal a paradox: while institutions, human capital and research, and business sophistication indicators demonstrate strong positive impacts, other indicators such as infrastructure, market sophistication, and creative outputs still present a detrimental effect on economic growth. This revelation underscores a critical challenge: despite the robustness of Singapore's

Table 12. Summary of study findings.

<i>Dependent: GDP</i>						
Variable	Panel	Time-series				
	Top Five SEA	Indonesia	Thailand	Singapore	Malaysia	Vietnam
GII	✓	✓	✓	✓	✓	✓
INS	✓	✓	✓	✓	✓	✓
HCR	✓	✓	✓	✓	X	✓
IFR	X	✓	✓	✓	✓	✓
MKS	✓	✓	✓	✓	✓	✓
BSS	✓	✓	✓	X	✓	✓
KTO	✓	✓	X	✓	✓	✓
CTO	✓	X	✓	✓	✓	✓

Note: ✓ (positive significant); ✓ (negative significant); and X (not significant).

innovation landscape, the supporting sectors crucial for sustaining economic growth still lag behind. This disparity highlights the complex interaction of factors shaping Singapore's economic trajectory, necessitating a nuanced approach to address the gaps and foster holistic development across all sectors [77–79].

Similar to Indonesia, Malaysia's GII indicators also reveal that only two out of the seven indicators positively impact economic growth: market sophistication and creative outputs. Conversely, indicators such as institutions, human capital and research, infrastructure, business sophistication, and knowledge and technology outputs still exert negative effects. This discrepancy may stem from suboptimal resource reallocation, where the process of shifting resources away from existing industries or technologies towards new ones is not yet optimized. Consequently, economic disruptions arise, impeding the overall country's economic growth [80–83].

Lastly, Vietnam's GII indicators indicate that six out of seven factors exert a negative influence on economic growth, with only business sophistication showing a positive impact. Indicators such as institutions, human capital and research, infrastructure, market sophistication, knowledge, technology, and creative outputs all still have a detrimental effect on economic growth. This observation aligns with conditions seen in Indonesia and Malaysia, where the innovation sector remains a hindrance to economic growth and is yet to be fully optimized. Innovation often requires significant upfront investments and entails risks before yielding economic benefits. Consequently, the costs associated with innovation may outweigh its advantages, resulting in an adverse effect on the economic growth [84–86].

4. Conclusions and Policy Recommendations

The empirical analysis across the top five SEA countries reveals a paradoxical relationship between innovation and economic growth. Despite indisputably showcasing the significant influence of innovation, the findings also challenge theoretical expectations by revealing that an

increase in innovation often corresponds with a decrease in economic growth. While some countries like Thailand demonstrate positive impacts of innovation on economic growth, others such as Indonesia, Singapore, Malaysia, and Vietnam face challenges where certain components of the innovation ecosystem hinder rather than facilitate economic growth. This intriguing discrepancy underscores the intricate nature of the relationship between innovation and economic prosperity in SEA, emphasizing the necessity for a nuanced comprehension of the distinct components and institutional frameworks surrounding innovation.

As each selected country in SEA faces unique challenges and opportunities in leveraging innovation for economic growth, policy recommendations should prioritize tailored strategies that address the specific challenges faced by each nation based on this study findings. Indonesia must prioritize bolstering infrastructure alongside efforts to enhance market sophistication and foster knowledge and technology outputs. Meanwhile, Thailand's focus should be on sustaining institutional support while concurrently investing in human capital and research, alongside promoting creative outputs across various sectors. Singapore, renowned for its robust innovation landscape, needs to address infrastructure shortcomings while enhancing market sophistication and fostering creative outputs to stimulate economic growth to a greater extent.

Furthermore, Malaysia must strengthen institutional support and increase investment in knowledge and technology outputs to drive innovation-led economic growth while promoting business sophistication among its enterprises. Vietnam, on the other hand, requires institutional reforms to foster a conducive environment for innovation and entrepreneurship alongside investments in human capital and research. Simultaneously, efforts to enhance market sophistication will be crucial for supporting business growth and innovation endeavors in the country. All specific policy recommendations recognize the diverse needs and

contexts of each country and are essential to unlocking the potential of innovation as a driver of sustainable economic growth in SEA.

Additionally, in considering the importance of this study, it's crucial to recognize its limitations, mainly due to the short duration of the data period utilized and its focus on just five countries in SEA. To advance research on the significant role of innovation in driving economic growth, future studies should aim to include a wider range of data periods and countries in their analysis. Moreover, a more dynamic method should also be considered to be employed so that long-term findings can be generated. This broader approach is expected to produce more comprehensive results, enhancing the current body of literature by providing a deeper insight into the relationship between innovation and economic growth.

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