International Summit on Science Technology and Humanity
ISETH 2025
ISSN: 2615-1588 (online)

Singapore's Economic Growth Dynamics

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Abstract

Purpose: this study employs an Error-Correction Model to examine how foreign direct investment (FDI), renewable energy consumption, labor, and inflation are associated with economic growth in Singapore
Methodology: Using annual Singapore data for 2000 to 2024, this study employs an Error-Correction Model to capture both short-run dynamics and long-run equilibrium relationships between FDI, renewable energy consumption, labor, inflation, and economic growth.
Results: The short-run estimates indicate that growth is responsive to FDI, renewable energy use, and inflation, whereas labor does not exhibit a statistically significant effect. In contrast, the long-run results reveal that renewable energy, labor, and inflation exert significant influences on growth, while FDI becomes non-significant. The specification accounts for 71.61% of the variation in economic growth.
Applications/Originality/Value: These findings point to the presence of frictions in the clean-energy transition and rigidities in the labor market, as well as an asymmetric contribution of FDI relative to renewables across time horizons. From a policy perspective, the implications include the importance of maintaining macroeconomic stability, accelerating the rollout of renewable energy, alleviating constraints in the labor market, and directing investment toward projects that enhance productivity.

Introduction

The economy plays a very important role as a main pillar in the life of a country. The level of welfare of a nation is reflected in its economic progress and development. As explained by Nurmilah & Saputra (2025) , development is ideally understood as a process of transformation from inadequate conditions to better ones, both physically and spiritually. In an economic context, development is a series of efforts aimed at encouraging economic growth, such as increasing the quantity and quality of infrastructure, growing the business sector, improving the quality of education, and advancing technology (Sholikhah et al. 2021). It's important to understand economic development as a process in order to analyze the interrelationships and influences between the various factors involved. With the approach, each stage of development and its impact on economic growth and improved community welfare can be identified gradually from one phase to the next.

Singapore's one of the most economically advanced and stable countries in Southeast Asia. As a country with significant natural resource constraints, Singapore faces significant challenges in maintaining and promoting economic growth that is not only rapid but also sustainable. In this context, sustainable economic growth refers to economic improvement that is able to meet current needs without compromising the ability of future generations to meet their needs, especially in relation to resource constraints and environmental impacts (Ghazy et al. 2025). Singapore's economic structure is heavily dependent on the service sector and high-tech manufacturing industry, supported by pro-investment and innovation government policies. However, various external and internal factors can pose challenges to long-run economic growth, such as limited natural resources and dependence on fossil fuel imports that are vulnerable to global price fluctuations. In addition, climate change is also a serious threat that could affect economic stability, making mitigation and adaptation strategies and integral part of development policy. This is reflected in the "Green Plan 2030", which focuses on reducing carbon emission and developing renewable energy as strategic steps for the future (Mitra et al., 2025).

Singapore's economic growth in 2025 is estimated to be in the range of 1 to 3%, reflecting global dynamics that are fraught with uncertainty, such as geopolitical tensions and supply chain disruptions. Nevertheless, Singapore continues to strive to maintain economic stability by diversifying and encouraging innovation (Ghazy et al., 2025). According to Gandhi et al. (2022), Singapore's growth is influenced by foreign direct investment, pro-growth economic policies, export and global trade performance, energy and infrastructure systems, the strength of human

capital and education, financial intermediation, technological innovation, and its strategic geographic position. FDI materially contributes to Singapore's growth by injecting modern technology, funding, and managerial know-how, thereby bolstering manufacturing and services, the nation's main drive. Singapore's success as a global trading hub is also supported by high volumes of goods and passenger traffic, the frequency of international trade exhibitions, and the large number of multinational companies operating in the country. All these factors contribute to inclusive and sustainable economic growth (Tarigan, 2021).

FDI functions as a primary catalyst for Singapore's development. Pro-investment policies have enabled the economy to draw sizeable inflows that, beyond funding, transfer advanced technologies, spur innovation, and diffuse management capabilities, reinforcing the manufacturing base and the service sector. FDI contributes significantly to increasing Singapore's productivity and economic competitiveness at the global level (Sibero, 2024). According to an official report from the Singapore Department of Statistics (2023), the amount of foreign investment in Singapore's corporate sector increased by 9.0% from SGD 2,608 billion at the end of 2022 to SGD 2,843 billion at the end of 2023. The main sources of FDI originated from North America (27%), Europe (26%), and South America and the Caribbean (23%), indicating that foreign investors in Singapore are widely diversified. CEIC Data from Singapore Department of Statistics (2024a), shows that Singapore's FDI reached 32.2% of nominal Gross Domestic Bruto (GDP) in December 2024, a significant increase from 24.5% in the previous quarter. This demonstrates the strategic role of FDI in driving the country's economy (Singapore Department of Statistics, 2024b). In addition, FDI not only increases production capacity, but also plays a role in transforming Singapore's economy from labor-dependent manufacturing into high-technology industry and knowledge-intensive services. This is in line with findings that FDI accelerates technology transfer and improves the skills of the local workforce, which ultimately strengthens the innovation and entrepreneurship ecosystem in Singapore (Thangavelu, 2023).

The synergy between foreign direct investment (FDI) and renewable energy consumption has been a major factor in driving sustainable economic transformation in Singapore, which depends on macroeconomic stability. On the other hand, Singapore faces a major threat from climate change due to fossil fuel consumption, which is estimated to affect up to 47% of GDP by 2048 if not addressed immediately. To overcome this challenge, the government has introduced the Green Plan 2023 as a national strategy for achieving sustainable development. This plan includes the development of solar energy, carbon emission reduction, and green technology innovation. The floating solar power plant project and ambitious solar energy capacity targets are clear evidence of Singapore's commitment to the transition to sustainable energy (Ade, 2025). Foreign investment not only brings capital and technology to the manufacturing and service sectors, but also encourages the transfer of green technology and clean energy innovation, which Singapore desperately needs to reduce its dependence on fossil fuels (Tran et al., 2025). Given its limited land and natural resources, Singapore's energy transition strategy focuses on developing renewable energy, particularly solar power, and diversifying energy sources through imports of clean electricity from neighboring countries. Through the Green Plan 2030, the government is targeting a solar energy capacity of 2 GWp by 2030, which could meet the needs of around 350,000 households per year (Food & Hospitality Asia (FHA), 2024). FDI serves as a critical source of funding support, research, and development of solar panel technology and energy storage system (ESS), Including the Sembcorp ESS project, which is the largest energy storage system in Southeast Asia (Do, 2024). In addition to developing solar energy domestically, Singapore is also strengthening regional electricity grid interconnections to import renewable energy from countries such as Indonesia, Vietnam, dan Kamboja. These efforts aim to increase the proportion of renewable energy 40% by 2035, a significant increase from only 4% in 2022, and reduce energy sector emission by 52-58% per capita by 2035 if the target is achieved (Setyawati & Lolla, 2024).

Investment in green technology is just one aspect of Singapore's transformation towards a sustainable economy, another aspect is the support of a flexible and competent labor force. The productive labor force aged between 15 and 64 is an important part of Singapore's economy. People aged between 15 and 64 have had a labor force participant rate above 80% for the five years, according to data from the Singapore Department of Statistics. The latest figure is 82.5% as of June 2024 (Singapore Department of Statistics., 2024). This stability reflects the readiness of human resources and demographic strength, which are the foundations of long-run economic growth. In addition, Singapore's post-pandemic economic resilience is highly dependent on its productive-age labor force, especially in the technology and service sectors (Remy, 2021). But, labor market inflexibility and skills mismatches that hamper productivity and efficiency are the fundamental problems facing Singapore's labor market. The Ministry of Trade and Industry found that construction and social services experienced productivity stagnation or contraction in 2020, while labor productivity per hour worked increased by just 1.3%. Furthermore, skills mismatch highlights the importance of skills upgrading and human capital development as key component of long-run economic growth, which can reduce economic efficiency (Abrha, 2025). Many studies show that, despite having a relatively large labor supply, labor contributions can decline if more people are employed without a corresponding increase in productivity and skill level on economic growth (OECD, 2025).

In recent years, Singapore has successfully maintained inflation at a relatively low and stable level. Controlled inflation is a key requirement for long-run investment in green energy and technological innovation, while ensuring that people's purchasing power remains intact amid global dynamics. The official projection for core inflation in 2025 has been revised in "Singapore's 2025 inflation to remain in the 1.5% and 2.5%" Monetary Authority of Singapore (MAS)" to a range 1–2%, while overall inflation is expected to be between 1.5–2.5% (Sharon, 2025). As shown in Figure 1, Singapore's GDP at current prices has trended upward between 2000 and 2024, reflecting a sustained expansion of economic activity. The latest data shows that annual inflation as of March 2025 stands at 1.71% , lower than the historical average, indicating the success of managing price pressures amid worldwide uncertainty (Singapore Department of Statistics, 2025). More flexible monetary policies, such as gradual adjustments in relation to the incline of the Singapore Dollar's nominal effective exchange rate, also support price stability and inclusive economic growth (Sharon, 2025). Controlled inflation provides cost certainly in the renewable energy sector, which is highly dependent on imports of technology and raw materials. Conversely, high inflation can increase the cost of green energy projects, squeeze profit margins, and hinder foreign investment flows into strategic sectors.

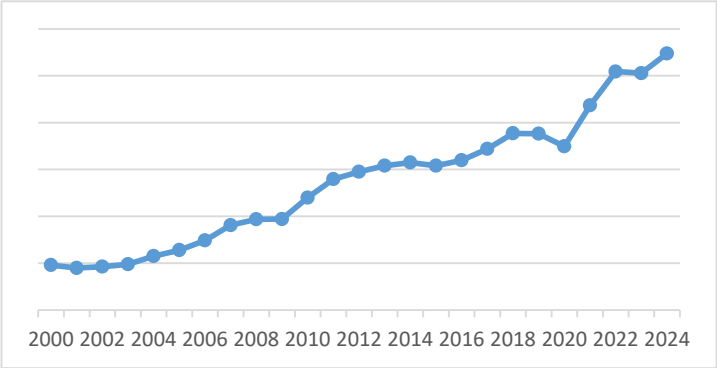

Figure 1 Singapore's Economic Growth from 2000 to 2024

GDP data in Figure 1 indicate how Singapore's economy has evolved between 2000 and 2024. Over this period, the country moved into a phase of recovery and subsequent expansion following the Asian financial crisis of the late 1990s. In nominal terms, GDP rose from about USD 96.06 billion in 2000 to roughly USD 115.03 billion in 2024, as depicted in Figure 1. The slowdown in global growth and the after-effects of monetary turbulence were mitigated by responsive macroeconomic policies that helped energize the services and technology sectors. Alongside this, the government's efforts to consolidate Singapore's role as a regional trade and logistics hub through infrastructure investment and efficiency improvements, together with export recovery, rising foreign direct investment (FDI), and broader economic diversification, underpinned the country's growth performance. Against this backdrop, it becomes important to highlight the joint influence of four key factors: FDI, renewable energy consumption, labor, and inflation stability. The growth pattern captured in Figure 1 is clearly shaped by more than purely domestic real-sector dynamics; it reflects how these macroeconomic and structural variables interact over time. Singapore provides a particularly suitable context for examining these interactions. It is a small, highly open, innovation driven economy that has sustained high income levels despite severe natural resource constraints. Its dependence on FDI, the shift toward advanced manufacturing and services, progress in renewable energy deployment, and a continuously upgraded labor force offer a rich setting to study the balance between short-term macroeconomic adjustments and longer-term structural transformation. Most empirical work in Southeast Asia has centered on larger emerging economies such as Indonesia, Malaysia, and Thailand, so there is still limited evidence on how growth is sustained in small, high-income, resource-limited economies. By focusing on Singapore over the 2000 to 2024 period and applying an Error-Correction Model (ECM), this study separates the short-run from the long-run effects of FDI, renewable energy consumption, labor, and inflation on economic growth. In doing so, it aims both to close part of this empirical gap and to offer insights that are useful for policymakers seeking to preserve growth while steering the economy toward a low-carbon, innovation-led development path.

Literature Review

Economic growth is a far-reaching process of change that reshapes a society's material and nonmaterial conditions; it is not simply a rise in GDP figures (Puri, 2020). It therefore signals long-run development encompassing advances in technology, education, infrastructure, and overall well-being. As Kuznetz (1996) notes, growth is a sustained

expansion in an economy's capacity to deliver a diverse array of goods to its people, supported by technological innovation, shifts in institutions, and ideological evolution (Madsen & Strulik, 2025). In surveys of the intellectual development of growth theory, scholars often differentiate between two major lineages. The first is the classical tradition, rooted in the writings of Adam Smith and David Ricardo, which highlights mechanisms such as specialization, the buildup of capital, and the gains arising from comparative advantage. The second is the modern or neoclassical line of thought, shaped by marginal analysis and formal treatments of technological change. Recent syntheses and retrospective assessments continue to underscore this two-part framework and explore its significance for current discussions on innovation-driven growth and long-run sustainability (Sunny & Jeronen, 2025).

Modern perspectives include the Harrod (1997) framework, which underscores the centrality of investment such as foreign investment that can yield differential returns, strengthen competitiveness, and improve transactional efficiency and green and sustainable energy investments, because investment both boosts demand and expands productive capacity through additions to the capital stock (Firmansyah et al., 2022). This aligns with Robert M. Solow's emphasis on capital formation, labor expansion in both quantity and quality via education and training, and technological change as key drivers of output growth (Lim et al., 2024). Solow argues that technological progress is indispensable for sustained gains in productivity and income per person. Even so, macroeconomic realities like labor-market rigidities can impede structural adjustment, slow job creation, and raise unemployment particularly in volatile periods contributing to inflation via wage pressures and rising input costs in materials and energy (Singh, 2023). In short, economic growth is more than a statistic; it is a dynamic, coordinated effort across multiple development levers aimed at broad-based and lasting prosperity.

Methodology

This research employs a quantitative time-series design with descriptive and causal comparative (ex post facto) elements to examine how the independent variables foreign direct investment (FDI), renewable energy consumption (REC), labor (LAB), and inflation (INF) affect Singapore's economic growth. The descriptive component outlines the evolution of key macroeconomic indicators over time, whereas the causal comparative (ex post facto) component tests proposed cause–effect linkages by analysing realized outcomes and inferring their underlying determinants from past data (Rahmi Pertiwi et al. 2023). This research relies on secondary quantitative data. This type of data is assembled and processed by outside organizations with access to journals, databases, or archives, and then employed in research (Watkins, 2024). The analysis draws on annual time series covering 2000 to 2024, obtained from the World Bank, MAS, Singapore Department of Statistics, EMA, IMF, and CEIC.

The data analysis method used in this study is the Error Correction Model (ECM) approach to examine the long-run and short-run relationship between integrated variables, even though the data is non-stationary and prone to spurious regression (Sitohang et al., 2025). The ECM model allows for a more accurate analysis of the relationship of economic variables that experience short-run imbalance but have a long-run equilibrium. In the error correction model (ECM), the specification consists of a long-run equation capturing the equilibrium relationship among variables and a short-run equation in which the error correction term (ECT) represents the speed of adjustment back to equilibrium; this framework is particularly valuable in empirical macroeconomic analysis because it incorporates short-run dynamics while remaining aligned with long-run economic relationships (Gujarati, 2009). The specification of the long-run estimator is as follows based on equation (1):

$$logGDP^*_t = \beta_0 + \beta_1 logFDI_t + \beta_2 REC_t + \beta_3 LAB_t + \beta_4 INF_t + \varepsilon_t \quad (1)$$

GDP represents the monetary value of all final goods and services generated in the country during 2000–2024, reported at current (nominal) prices rather than in inflation adjusted terms. FDI refers to foreign direct investment capital placed directly into Singaporean firms or other productive assets reported in USD. REC captures the percentage share of electricity generated from renewable energy sources at the national level. LAB denotes the labor-force participation of those aged 15–64, covering both the employed and those actively seeking jobs (%). INF captures CPI inflation on a year-over-year basis (%). This follows established macro conventions that prioritize CPI-derived measures for reliable consistency across countries. The log (ln) operator denotes the natural logarithm; it helps stabilize variance and lets coefficients be read as elasticities. β_0 is the intercept of the long-run estimating equation, while $\beta_1, \beta_2, \beta_3$ and β_4 the long-run slope coefficients associated with FDI, REC, LAB, and INF, respectively. ε is the disturbance (error) term, and t indexes the year.

Consistent with the Domowitz and Elbadawi framework, the partial adjustment mechanism is derived as the solution to a quadratic cost-minimization problem. This methodology was empirically implemented by Dondok et al. (2024) in comparable context and after minimization, algebraic rearrangement, and parameterization, the standard short-run ECM specification is shown in Equation (2):

$$\Delta logGDP^*{}_t = \alpha_1 \Delta logFDI_t + \alpha_2 \Delta REC_t + \alpha_3 \Delta LAB_t + \alpha_4 \Delta INF_t - \lambda\ logFDI_{t-1} - \lambda\ REC_{t-1} - \lambda\ LAB_{t-1} - \lambda\ INF_{t-1} + \upsilon_t \quad (2)$$

Here, Δ is differencing operator, $\alpha_1, \alpha_2, \alpha_3,$ and α_4 describe the short-run influence of FDI, REC, LAB, and INF, λ is adjustment coefficient, shows the rate of long-run equilibrium. A large and negative value signifies the validity of the ECM model and the process of the dependent variable adjusting towards long-run equilibrium. Here υ denotes the disturbance run. More generally, the short-run estimation model can be expressed as Equation (3):

$$\Delta logGDP^*{}_t = \gamma_0 + \gamma_1 \Delta logFDI_t + \gamma_2 \Delta REC_t + \gamma_3 \Delta LAB_t + \gamma_4 \Delta INF_t + \gamma_5 logFDI_{t-1} + \gamma_6\ REC_{t-1} + \gamma_7\ LAB_{t-1} + \gamma_8\ INF_{t-1} + \gamma_9\ ECT_{t-1} + \omega_t \quad (3)$$

Then, $\gamma_1, , \gamma_2, \gamma_3, \gamma_4$ are all equal to $\alpha_1, \alpha_2, \alpha_3,$ and $\alpha_4$which are the model's independent variable coefficient. When is multiplied by $(1-\beta_1)$, $(1-\beta_2)$, $(1-\beta_3)$, $(1-\beta_4)$, the coefficient $\gamma_5, \gamma_6, \gamma_7, \gamma_8$ are obtained. These coefficients show the extent to which the independent variables have been adjusted after accounting for their long-run impacts. The estimated model's error term, which represents extraneous aspects that the model's variables are unable to account for, is finally represented by the symbol *ω*. While the main component of the ECM model, error correction term, is ECT_{t-1} which indicates the rate at which the dependent variable readjusts to its long run equilibrium following a disturbance. Here is the estimation model expressed as Equation (4):

$$ECT_t = logFDI_{t-1} + REC_{t-1} + LAB_{t-1} + INF_{t-1} - logGDP_{t-1} \quad (4)$$

ECM estimation was preceded by standard multiple-regression diagnostics to evaluate how FDI, renewable energy consumption, labor, and inflation affect economic growth. To ensure the findings were valid for policy decisions, tests were performed for residual normality, autocorrelation, heteroscedasticity, multicollinearity, and residual linearity.

Results and Discussion

1. Estimation Results

The short run ECM results and related tests are presented in Table 1.

Table 1

Short-run ECM Model Estimation

$$\widehat{\Delta logGDP_t} = 2.0370 + \underset{(0.0145)^{**}}{0.0964}\ \Delta logFDI_t - \underset{(0.0125)^{**}}{0.0803}\ \Delta REC_t + \underset{(0.7466)}{0.0064}\ \Delta LAB_t + \underset{(0.0354)^{**}}{0.0163}\ \Delta INF_t - \underset{(0.1897)}{0.1038}\ logFDI_{t-1} - \underset{(0.0097)^{*}}{0.3216}\ REC_{t-1} - \underset{(0.0337)^{**}}{0.2035}\ LAB_{t-1} - \underset{(0.0338)^{**}}{0.2188}\ INF_{t-1} + \underset{(0.0360)^{**}}{0.2215}\ ECT_{t-1}$$

$R^2 = 0.7169$; *DW-Stat.= 2.5023; F-Stat= 4.2224; Prob. F-Stat.= 0.0069*

Model Diagnostic

1. Multicollinearity (VIF)
   $\Delta logFDI_t = 2.4294$; $\Delta REC_t = 4.8441$; $\Delta LAB_t = 1.4852$;
   $\Delta INF_t = 1.9144$; $logFDI_{t-1} = 32.7731$; $REC_{t-1} = 55.7636$;
   $LAB_{t-1} = 337.1701$; $INF_{t-1} = 307.5546$; $ECT_t = 1144.453$
2. Normality of Residual (Jarque Bera)
   JB (2) = 2.9644; Prob. JB (2) = 0.2271

3. Autocorrelation Diagnostic (Breusch-Godfrey)
   $\chi^2(3) = 4.6617; Prob.\chi^2(3) = 0.1983$
4. Heteroskedasticity (White)
   $\chi^2(18) = 17.7287; Prob.\chi^2(18) = 0.4737$
5. Linearity (Ramsey Reset)
   $\chi^2(2.13) = 2.7948; Prob.\chi^2(2.13) = 0.0978$

Sources: World Bank. **Notes**: * indicates significant at α = 0.01; ** indicates significant at α = 0.05; *** indicates significant at α = 0.10. Values in parentheses represent the p-value (empirical probability) for the t-statistic.

From Table 1, the ECT (adjustment coefficient, λ) is 0.2215, well within the $0 < \lambda < 1$ interval. Its p-value or empirical statistical t-probability is 0.0360, indicating the adjustment coefficient is statistically significant α = 0.05. These conditions establish that the estimated model is an ECM. As a result, its error-correction term facilitates attainment of the long-run theoretical equilibrium relating the independent and dependent variables.

Based on the definition of short-run parameters, the estimated long-run ECM model are presented in Table 2.

Table 2 Estimated Long Run ECM

Variables	Parameters	Calculation	Results
	$\lambda = \gamma_9$	0.2215	0.2215
Constant	$\beta_0 = \frac{\gamma_0}{\lambda}$	$\frac{2.0370}{0.2215}$	9.1964
FDI	$\beta_1 = \frac{\gamma_5 + \lambda}{\lambda}$	$\frac{-0.1038+0.2215}{0.2215}$	0.5313
REC	$\beta_2 = \frac{\gamma_6 + \lambda}{\lambda}$	$\frac{-0.3216/0.2215}{0.2215}$	- 0.4519
LAB	$\beta_3 = \frac{\gamma_7 + \lambda}{\lambda}$	$\frac{-0.2035/0.2215}{0.2215}$	0.0812
INF	$\beta_4 = \frac{\gamma_8 + \lambda}{\lambda}$	$\frac{-0.2188/0.2215}{0.2215}$	0.0121

Source: Secondary data that have been processed

According to the long-run parameter estimates in Table 2, the long-run equation can be stated as Equation (5):

$$logGDP^*_t = 9{,}1964 + 0{,}5315\ logFDI_t - 0{,}4519\ REC_t^* + 0{,}0812\ LAB_t^{**} + 0{,}0121\ INF_t^{**} \quad (5)$$

Table 1's diagnostic checks show p-value for the normality of residual, autocorrelation, heteroscedasticity, and linearity are validated of 0.2271 (> 0.10), 0.1983 (> 0.10), 0.4737 (> 0.10), and 0.0978 (> 0.05), respectively. The results indicate that the model's residuals are normally distributed and that there is no evidence of autocorrelation or heteroscedasticity, consistent with a correctly specified linear model. All variables record VIF<10, except for $logFDI_{t-1}$ at 32.7731, REC_{t-1} at 55.7636, LAB_{t-1} at 337.1701, INF_{t-1} at 307.5446, and ECT of 1144.453, indicating multicollinearity issues driven by these lagged variables.

The goodness-of-fit indicators validate the model specification, with an F-test p-value of 0.0069 (< 0.01) and an R^2 of 0.7169, implying that FDI, REC, LAB, and INF jointly explain 71.69% of the variation in Singapore's GDP, while the remaining 28.31% is driven by factors outside the model. In the short run, Singapore's GDP growth is driven by FDI, REC, and INF, whereas LAB is not statistically significant; in the long run, GDP is mainly explained by REC, LAB, and INF, while FDI becomes insignificant.

In the short run, FDI's estimated parameter equals 0.0964, this variable's association with GDP is modeled in a log–log specification. This means that if foreign direct investment (FDI) increases by 1%, GDP will increase by 0.0964 %; conversely, if FDI decreases by 1%, GDP will decrease by 0.0964%. In the long-run specification, FDI is not impactful.

In the short run, renewable energy consumption coefficient is −0.0803, while the relationship with GDP is captured using a log–linear specification. This means that if REC increases by 1%, GDP will decrease by 0.0803 x 100 = 8.03%; conversely, if renewable energy consumption (REC) decreases by 1%, economic growth (GDP) will increase by 0.0803 x 100 = 8.03%; In the long run, the REC coefficient is -0.3216. The relationship pattern between these variables and the GDP variables is log-linear. This means that if REC increases by 1%, GDP will decrease by 0.3216 x 100 = 32.16%; conversely, if REC decreases by 1%, GDP will increase 32.16%.

For the short run, the estimated log–linear coefficient on inflation is 0.0163, implying that a 1% increase in INF corresponds to roughly a 1.63% gain in GDP. In the long run, INF enters the log–linear model with a coefficient of − 0.2188. Thus, a 1% rise in INF is associated with roughly a 0.2188 x 100 = 21.88% decline in GDP; conversely, a 1% decrease in INF correlates with an increase in economic growth (GDP) of 21.88%.

In the short run, the labor force variable has no significant effect on GDP. In the long-run specification, the variable's effect is captured by a coefficient of −0.2035, and the association with GDP follows a log–linear pattern. This means that a 1% increase in LAB can reduce GDP by 0.2035 x 100 = 20.35%; conversely, if LAB falls by 1%, GDP is expected to rise by about 0.2035 x 100 = 20.35%.

2. Discussion

The empirical estimates show that, in the short run, Singapore's output growth is primarily driven by foreign direct investment, renewable electricity use, and inflation, whereas the labor variable does not play a statistically meaningful role. In the longer horizon, the influence of FDI fades, while renewable energy consumption, labor, and inflation become significant determinants of growth. At the same time, several long-run coefficients exhibit signs and significance patterns that do not fully align with standard growth theory. Therefore, this section reinterprets our findings in light of recent empirical studies and highlights the structural idiosyncrasies of Singapore the structural idiosyncrasies of Singapore, notably its pronounced reliance on renewable energy supported by subsidies rigidity in the labor market, and FDI spillovers that depend on domestic absorptive capacity as plausible explanations for these discrepancies.

The ECM estimates reveal an asymmetric FDI growth nexus in Singapore's: foreign direct investment exerts a positive and statistically significant effect on GDP in the short run, but its long-run impact is weak and not robust once adjustment dynamics are taken into account. The ECM estimation shows that, in the short run, the log–log coefficient on FDI is 0.0964, meaning that a 1% rise in foreign direct investment is associated with roughly a 0.0964% increase in GDP, holding other factors constant. This positive and statistically significant elasticity is in line with conventional growth theory, which posits that foreign capital inflows expand the production base and stimulate output over the short run. In practice, short-run movements in FDI in Singapore tend to support growth by enlarging productive capacity and improving firm-level efficiency. Annual inflows, either as equity for greenfield projects or as purchases of existing assets, add to the capital stock and push domestic output upward. This effect is amplified by pro-investment strategies that attract multinational enterprises into strategic sectors such as advanced manufacturing, financial services, and digital industries. Empirical evidence from Alfiyahnur & Juliannisa (2023), reports that short-run variations in Singapore's growth are strongly connected to FDI, primarily through scale economies in key sectors and the spread of managerial and technological know-how. Similarly, Obinna et al. (2025) They show that FDI not only adds to production capacity but also brings in technology and know-how that strengthen competitiveness, while faster growth then attracts further inflows, creating a virtuous feedback between investment and output. Together with our short-run estimates, this supports the view that FDI is a key short-term engine of growth, especially when backed by targeted measures such as tax incentives, infrastructure provision, and streamlined regulation. In a setting like Singapore, with strong institutions and macroeconomic stability, foreign capital can rapidly boost output and accelerate sectoral upgrading, making it an effective short-run policy tool. However, the long-run FDI elasticity of about 0.5313 is not statistically significant, indicating that its permanent impact on GDP is limited once adjustment dynamics and structural features are taken into account an outcome that departs somewhat from standard growth theory but is consistent with empirical work showing that long-run FDI effects are often weak or highly conditional. While Gandhi et al. (2022) emphasize the importance of FDI for growth in Southeast Asia particularly in the case of Singapore indicating that foreign capital can be a central engine of expansion when conditions are favourable other research documents negligible or even adverse long-run impacts when local absorptive capacity, innovation systems, and financial development are insufficiently robust. Consistent with this view Nguyen and Thrinh (2022), show that the long-run benefits of FDI are critically shaped conditioned on the quality of institutions and the depth and sophistication of the local financial system. In the absence of policies that tie foreign capital to national R&D, domestic firms, and strategic sectors, FDI may result in enclave-type growth concentrated in a few activities Chizema (2025) similarly warns that when inflows are not aligned with sectors that drive structural change, they can reinforce external dependence and hinder sustainable development; in advanced economies such as Singapore, a heavy reliance on foreign capital particularly when fiscal incentives disproportionately favor foreign over domestic firms may also displace local investment.

Renewable energy consumption has a twofold impact on Singapore's, In the short run, the coefficient on renewable energy consumption is positive and statistically significant, indicating that greater use of renewables is associated with stronger economic growth. After controlling for adjustment dynamics and relevant structural factors, the estimated long-run elasticity is −0.4519, which implies a persistent negative effect on output. This only partly

matches green-growth and endogenous growth theory, which generally expects renewables to boost performance in both horizons by enhancing energy security and driving innovation. In essence, the estimates suggest that renewables act as a short-run stimulant to growth, whereas in the long run their expansion is limited by frictions and cost-related pressures (Wang Shuang, 2024). In practical terms, higher renewable energy consumption raises growth in the short run through the rapid deployment of clean-energy capacity and a more diversified energy mix, which cushions the impact of global price shocks and contributes to macroeconomic stability. Jia & Xia (2023) find comparable findings for open and developing economies, indicating that greater use of renewable energy can raise economic growth by enhancing energy efficiency and reducing reliance on imported fuels. In the long run, however, the transition encounters more deep-rooted obstacles: many renewable sources, particularly solar and wind, are intermittent and require costly storage systems and grid reinforcement; substantial upfront capital requirements, ongoing operating expenses, and adjustment pressures in labor markets and technology adoption can place significant strain on the public budget. This evidence supports the argument that, when efficiency gains are incomplete and policy support remains heavily subsidy-based, the energy transition cannot yet be fully embedded in the growth model and may even result in weak or unfavourable long-run effects (Arrohmah & Sukim, 2024). In accordance with the crowding-out hypothesis in public finance, sizeable budgetary commitments to renewable-energy subsidies can reduce the fiscal room available for other high-return investments such as education, healthcare, and R&D which in turn may lower an economy's growth potential (Taylor, 2020). Egbe et al. (2024) arrive at a similar assessment, emphasizing that while renewables are effective in cutting emissions, their long-run impact on growth is highly contingent on the design of subsidy schemes and the overall soundness of the public finances. A more optimistic assessment is found in studies that evaluate renewable expansion in conjunction with economy-wide efficiency improvements. Mafruhah et al. (2024) show that when efficiency gains spread across transport, industrial activity, households, and infrastructure, additional renewable energy use can yield sizeable long-run output gains on the order of 32.16% of extra economic growth per additional unit of energy consumed. This result is consistent with Beck et al. (2025), who argue that sustained economic growth can reinforce energy efficiency by facilitating the diffusion of new technologies. More recent work further underscores that the durability of these benefits hinges on complementary measures in three key areas: technological innovation in clean energy, responsive and adaptive regulatory frameworks, and evolving demand-side behaviour in energy consumption (Bhuiyan et al., 2022). For Singapore, concrete transition moves such-as floating solar deployment, deeper regional grid interconnections, and a 2 GWp solar target by 2030 illustrate how renewables can become a new engine of growth, so long as they are anchored by responsive governance, sustained investment in technology, and parallel demand-side efficiency improvements.

Singapore's growth dynamic around labor can be read as a two-stage story. In the short run, the estimated labor coefficient is low and not statistically significant, suggesting that fluctuations in employment have only a modest immediate impact on economic growth because skills mismatches, limited movement across sectors, and slow adoption of new technologies hinder the efficient reallocation of workers (Giupponi & Machin, 2024). This aligns with Pratama et al. (2020), who show that when labor markets are rigid and human capital is weak, additional employment does not translate into higher output, so headcount expansion without productivity gains fails to spur short-run growth. In such settings, labor acts as a constraint rather than a growth engine and only supports expansion once skills are upgraded, labor-market efficiency improves, and access to vocational, industry-oriented training is widened. Consistent with our negative long-run labor coefficient, this implies that in Singapore, institutional rigidities, skill mismatches, and stagnant productivity in labor-intensive sectors can cause employment growth without parallel efficiency improvements to weigh down aggregate productivity and overall performance. In the same spirit, DBS Flash Singapore, caution that expanding employ-ment without parallel improvements in manufacturing productivity weakens operational performance and hampers long-run growth: when firms add workers faster than they upgrade processes or implement new technologies, economies of scale deteriorate and productivity stalls. In this light, our small and insignificant short-run labor coefficient, together with the negative and significant long-run estimate, is indicative of a setting where employment growth is driven by headcount rather than capability, highlighting the importance of policies that promote upskilling, greater inter-sectoral mobility, and wider adoption of technology at the firm level so that labor deepening feeds into higher productivity instead of additional friction. This is consistent with Menon (2021) contention that Singapore's future prosperity rests less on expanding the workforce and more on strengthening productivity and innovation. Nonetheless, evidence from other studies suggests labor is positively and significantly associated with long-run outcomes (Lazuardi & Muttaqin, 2023). Mohi and Dai (2022) find that, throughout their sample period, labor contributes positively and significantly to regional economic output, particularly when accompanied by higher investment and gains in efficiency. Their results indicate that a better-skilled, more productive labor force, when combined with capital deepening and technological upgrading, can foster stronger growth, an outcome consistent with the Solow model and with theoretical perspectives that highlight the complementary roles of capital, labor, and technology in shaping operational performance (Yuniartika, 2022).

Inflation plays a significant but mixed role in Singapore's growth dynamics. In the short run, the positive and significant log–linear coefficient of 0.0163 indicates that a 1% increase in inflation is linked to a proportional rise in economic growth, suggesting that moderate, well-anchored price increases can temporarily boost demand by bringing forward spending and investment. This aligns with Singapore's recent experience of low and stable inflation, which has allowed the Monetary Authority of Singapore to support consumption without undermining overall macroeconomic stability (Singapore, 2024). El Waly & Bouchra (2021), previous studies similarly find that inflation exerts a positive and significant short-run effect on output, in line with evidence from the *Asian Economic Journal* that moderate inflation can boost growth in ASEAN economies by stimulating real-sector activity and improving resource allocation through relative price changes. However, in the long run our ECM estimates show a negative and significant inflation coefficient −0.2188, indicating that once adjustment dynamics and structural factors are accounted for, persistent inflation ultimately dampens economic growth (Sanida & Rahayu, 2022). This long-run finding aligns with the view that persistent inflation undermines efficiency and skews portfolio choices: investors shift into inflation-hedging assets, while high, poorly anchored inflation reduces monetary-policy effectiveness and discourages FDI as foreign investors expect real returns to be eroded (Nguyen, 2023). This reallocation of funds away from productive investment can damage Singapore's long-run growth prospects (Saidi & Ochi, 2023). Particularly for risk-averse investors who require yields safely above the inflation rate, and it also accords with "three-shot effect" or threshold-inflation theories, which argue that low, moderate inflation may coincide with expansion, but once it surpasses a certain threshold it becomes harmful to growth (Purnomo & Wibowo, 2024). Evidence from the International Monetary Fund (2024) for Singapore supports this interpretation: living costs have been rising faster than nominal wages, eroding real incomes, weakening household spending, and adding pressure to socio-economic conditions. In line with studies that document weak or non-linear inflation growth relationships, our findings suggest that inflation's effect is shaped by institutional credibility, the policy regime, and how firmly expectations are anchored. Under these conditions, the ECM results place Singapore among economies where low and stable inflation is growth-supportive in the short run, whereas persistent price increases hinder long-run performance. Seen this way, the deviation of several long-run coefficients from standard theoretical predictions does not amount to a rejection of growth theory; rather, it suggests that in a small advanced economy the incremental effects of FDI, labor, and subsidised renewable energy depend critically on absorptive capacity, labor market functioning, and the design of macro-fiscal and energy policies.

Conclusion

Singapore's sustainable growth reflects horizon-dependent interactions among FDI, renewable electricity consumption (REC), labor (LAB), and inflation (INF). The ECM cleanly separates these forces: in the short run, output co-moves with FDI, REC, and inflation, while labor is statistically muted; over longer horizons, REC, LAB, and inflation become the principal drivers as FDI's direct effect wanes. Short-run FDI gains likely stem from swift capital deepening and technology transfer into high-productivity sectors. REC boosts short-run activity through investment in generation assets and grid upgrades, with durable payoffs arriving via reduced energy-price volatility, learning spillovers, and decarbonization premiums that lift total factor productivity. Inflation behaves pro-cyclically at high frequency often a signal of demand and capacity use yet persistent price pressures erode competitiveness and deter investment.

Model performance is solid: the ECM explains about 71.69% of growth variation (R^2= 0.7169) and identifies convergence toward long-run equilibrium. Policy should, first, channel greenoriented FDI into deep domestic linkages (supplier development standards and R&D co-investment); second, accelerate renewable energy consumption with enabling infrastructure (storage, flexible grids, demand response) and stable pricing framework; and third, raise labor quality through continuous upskilling, targeted talent inflows, and productivity incentives while anchoring inflation via credible monetary and macroprudential coordination. Key caveats include nominal GDP measurement, possible structural breaks, and variable definitions; future work could test asymmetric or threshold ECMs and sector-specific FDI channels.

This study has several limitations that should be acknowledged. The analysis relies on annual secondary data from 2000 to 2024, which may not fully capture short-run fluctuations or quarterly variations that could influence Singapore's economic growth. In addition, the use of aggregate national data limits the ability to distinguish sectoral dynamics, such as the differing effects of foreign direct investment and renewable energy use across manufacturing, services, and technology industries. The model also employs a limited number of macroeconomic variables due to data constraints, excluding potentially important factors such as technological innovation, trade openness, and institutional quality. Moreover, this study adopts a linear Error Correction Model (ECM) framework, which may not completely reflect the nonlinear or asymmetric characteristics of economic relationships in a small and highly open economy like Singapore. These constraints imply that the findings need to be viewed with a degree of caution and they also open up multiple promising directions for subsequent research.

For future research, it is recommended to strengthen the methodological and theoretical scope of the analysis. Future studies could apply more advanced econometric models such as the Threshold Error Correction Model (TECM), the ARDL Bounds Testing approach, or even a panel ECM framework to detect possible structural breaks, asymmetric responses, and cross-country variations. Incorporating additional explanatory variables such as indices of innovation capability, human capital quality, or environmental policy effectiveness would provide a more comprehensive understanding of the determinants of long-run economic growth. It would also be valuable to conduct comparative studies between Singapore and other small, high-income economies such as Hong Kong, South Korea, or Luxembourg to determine whether the observed patterns are unique to Singapore or reflect a broader trend among innovation driven nations. From a theoretical standpoint, future research could integrate endogenous growth theory and green growth frameworks to explain how innovation, sustainability, and institutional quality interact to support long-run economic resilience.

From a practical perspective, the findings of this study carry meaningful implications for policymakers and practitioners. The results highlight the importance of directing foreign direct investment toward sectors that generate strong domestic linkages, encourage technological diffusion, and create sustainable value-added activities. Enhancing renewable energy infra-structure and expanding investment in green innovation are also essential for strengthening Singapore's energy security and reducing dependence on fossil fuel imports. Maintaining price stability through prudent monetary policy while promoting productivity-oriented labor development will support inclusive and sustainable growth. For industry practitioners, these findings underscore the need to align business strategies with Singapore's Green Plan 2030 through the adoption of clean technologies, digital transformation, and workforce upskilling initiatives. Collaboration between government, academia, and industry will be critical to ensuring that Singapore's economic progress remains competitive, innovative, and environmentally sustainable.

Acknowledgement

We wish to extend our deepest appreciation to the Faculty of Economics and Business and the Development Economics Study Program, Universitas Muhammadiyah Surakarta (UMS), for their institutional support and for providing the research facilities that made this study possible. We also sincerely thank our colleagues from various partner universities for the valuable discussions during the research process, as well as the reviewers for their thoughtful comments and constructive suggestions, which have substantially helped to improve the quality of this manuscript. Finally, we are profoundly grateful to our parents, families, and friends for their unwavering encouragement, patience, and moral support throughout the completion of this research.

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