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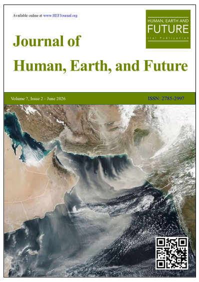

Green Technology and Urbanization as Catalysts of Sustainable Economic Development in Malaysia's Emerging Economy

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Abstract

The emergence of a new phase of urbanization, characterized by innovation, green development, and smart transformation, is increasingly shaping Malaysia's economic trajectory. Green technological innovation has become a critical driver in addressing sustainability challenges and strengthening the developmental momentum of urban construction. This study therefore examines the role of capital accumulation, labor force participation, human capital, financial development, urbanization, green technology, information and communication technology (ICT), and foreign direct investment (FDI) in promoting Malaysia's economic growth. Using annual data from 1991 to 2024, the analysis employs the Autoregressive Distributed Lag (ARDL) model, supported by robustness checks through Fully Modified OLS (FMOLS) and Canonical Cointegrating Regression (CCR). The findings indicate that urbanization, labor, capital, and green technology significantly contribute to economic growth in both the short and long run. Conversely, human capital and financial development show negative long-term effects, while ICT and FDI display limited or statistically insignificant impacts. Overall, the results highlight that although Malaysia has benefited from urban expansion, capital deepening, and the adoption of green technologies, structural weaknesses, particularly in education quality, financial sector efficiency, and effective FDI integration, continue to hinder the country's prospects for sustained long-term growth.

Keywords: Urbanization; Green Technology; Economic Development; FDI; Malaysia.

1. Introduction

Urbanization and green technology are increasingly recognized as critical drivers of modern economic growth. Urbanization promotes agglomeration economies, infrastructure development, and labor market efficiency [1] while

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green technology lays the foundation for sustainable growth by reducing environmental costs and enhancing resource efficiency [2]. Importantly, these two forces are not mutually exclusive: green technology can enhance urbanization by making cities more sustainable, livable, and attractive for investment, while urbanization, in turn, creates demand and opportunities for the adoption of cleaner technologies [3]. Together, they shape the pathways toward long-run economic growth that balances productivity with sustainability, a relationship that is especially relevant for developing and middle-income economies such as Malaysia [4, 5].

The relationship between urbanization and GDP growth has been studied extensively, with mixed results. Classical theories highlight that migration toward cities fosters growth through labor pooling, knowledge spillovers, and specialization [6]. More recent evidence suggests that the type of urbanization matters: growth driven by migration to urban centers correlates strongly with economic expansion, while natural population increases in cities do not. Studies across South Asia, Africa, and Sub-Saharan economies [1, 7, 8] consistently highlight that well-managed urbanization contributes positively to productivity, industrialization, and service sector expansion. Yet, some research also suggests possible reverse causality, where economic growth precedes and drives urbanization [9]. These debates show that while urbanization is often a catalyst for growth, its effectiveness depends on structural conditions, policy frameworks, and the quality of planning.

Parallel to urbanization, green technology has emerged as a vital determinant of long-run economic growth. Green technology adoption fosters sustainable development by promoting industrial transformation, reducing CO_2 emissions, and enhancing total factor productivity [2, 10]. Evidence from G7 and ASEAN economies shows that green technology contributes significantly to green GDP and complements foreign direct investment and globalization in driving sustainable outcomes [4, 5]. In addition, studies from China and Singapore confirm that green innovation positively contributes not only to growth but also to environmental quality, thereby resolving the trade-off between economic expansion and environmental sustainability [11, 12]. Thus, green technology is not merely a corrective tool for pollution but an engine of structural economic upgrading and competitiveness.

The relationship between urbanization and green technology is increasingly recognized as synergistic. Green technology innovations promote sustainable forms of urbanization by improving energy efficiency, supporting eco-friendly infrastructure, and enabling smart city development [3, 13]. Conversely, concentrated urban hubs provide fertile ground for the diffusion of technological innovation, particularly in renewable energy, ICT, and transportation. Research shows that renewable energy technology innovation can accelerate urbanization by raising productivity, improving industrial structures, and expanding rural-urban income linkages. At the same time, urban demand pressures encourage governments and firms to prioritize investment in green innovation, creating a reinforcing cycle. This nexus underscores why examining urbanization and green technology together provides a more holistic understanding of economic growth dynamics.

Malaysia provides a compelling context for examining the joint impact of urbanization and green technology on economic growth. The country has undergone rapid urbanization, with over 79% of its population living in urban areas as of 2024, reflecting its transition toward an urban-industrial economy [14]. The government has actively advanced sustainability through major policies: the Green Technology Master Plan (2017–2030) for long-term green innovation, the New Industrial Master Plan 2030 to embed sustainability in industrial upgrading, the National Energy Transition Roadmap (2023–2050) to achieve net-zero emissions, and the newly tabled 13th Malaysia Plan (2026–2030), which targets low-carbon growth and a 35% renewable energy share by 2030. Together, these initiatives highlight Malaysia's dual ambition to harness urbanization for competitiveness while driving green technology for sustainability.

Figure 1 highlights Malaysia's dual transition through two key indicators: the urban population growth rate and green technology adoption measured by patent applications per capita. Urbanization shows a steady increase from the early 1990s to 2024, reflecting the country's demographic and economic shift toward an urban-industrial economy. Meanwhile, green technology adoption experienced fluctuations in the late 1990s and around the 2008 global financial crisis, before stabilizing at modest levels and showing resilience even during the COVID-19 period. This divergence highlights the importance of studying their combined impact: while urbanization provides opportunities for growth, it also creates environmental pressures that demand sustainable solutions, and green technology offers the potential to mitigate these challenges by supporting sustainable and inclusive development.

Despite abundant research on urbanization, green technological innovation (GTI), and environmental outcomes, the literature remains fragmented and tends to analyse these forces in isolation rather than as an integrated growth system [15]. Most existing studies emphasize emissions, energy use, and green development outcomes, rather than economic performance [16-18]. In the Malaysian context, available evidence is especially narrow, as research largely focuses on environmental degradation using time-series techniques, while urbanization is treated mainly as a control variable rather than a growth mechanism [17, 18]. Moreover, critical transmission channels such as foreign investment, industrial upgrading, and renewable energy adoption remain underexplored [13, 19]. This reveals a clear empirical gap for a Malaysia-specific investigation that integrates urbanization and green technology within a unified growth framework.

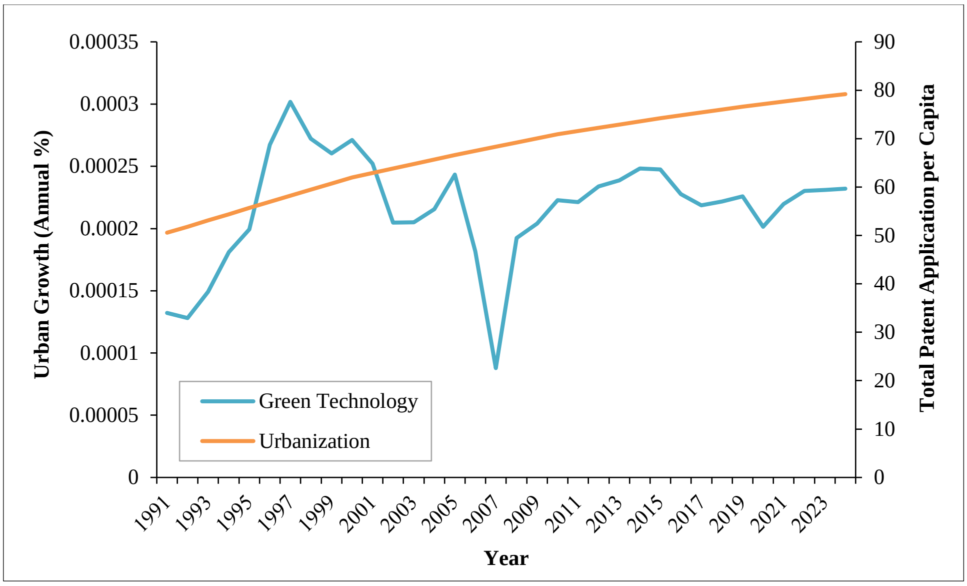


Figure 1. Malaysia urbanization and green technology

This study addresses these gaps by setting two key objectives: (1) to examine the impact of urbanization on Malaysia's economic growth, and (2) to investigate the contribution of green technology adoption to sustainable economic development in Malaysia. Using an extended endogenous growth framework, the study finds that while urbanization exerts a stronger direct impact, green technology plays a critical complementary role in ensuring sustainability. The novelty of this paper lies in integrating the urbanization–green technology nexus within Malaysia's growth trajectory, providing new empirical evidence and policy insights for balancing economic expansion with environmental resilience.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature, Section 3 outlines the methodology, Section 4 presents and discusses the results, and Section 5 concludes with policy recommendations.

2. Literature Review

Green technological innovation is a crucial component in addressing issues with development motivation and environmental constraints in urbanization. The degree of urbanization and green technological innovation has been quantified using the entropy approach and the super-efficiency DEA method, respectively. Furthermore, based on this, we assess the direct influence of green technological innovation on urbanization and its three dimensions, population, industrial, and ecological, using the panel regression model and the FGLS model. The indirect effects of green technology innovation on urbanization are then further investigated using the mediating effect model. According to the findings, the most effective strategy for promoting the growth of new urbanism at present is green technical innovation. Furthermore, while the impact of industrial structure optimization is negligible, green technology innovation might indirectly influence urbanization through the effects of foreign capital, energy consumption, and information development [13].

Guo et al. [20] examined the impact of green technology innovation (GTI) on urban carbon emissions in Chinese cities reveals that GTI generally reduces carbon emission intensity by improving energy efficiency, industrial upgrading, and environmental regulation enforcement. Using data from over 200 cities between 2005 and 2020, spatial econometric models show significant spillover benefits where innovation in one city helps reduce emissions in neighbouring cities, especially in more developed eastern regions. However, despite these gains, a rebound effect exists where efficiency improvements sometimes lead to increased economic activity and thus absolute emissions do not decline proportionally. The literature also highlights regional heterogeneity, with weaker low-carbon effects in resource-dependent and less developed areas. Methodological advances address spatial dependencies, but there remains a research gap in analyzing the post-2022 period under China's dual-carbon goals and in exploring finer spatial differences beyond prefecture cities, limiting understanding of GTI's full potential for urban carbon mitigation. This indicates a need for updated empirical studies incorporating recent policy shifts and city-tier distinctions to better inform sustainable urban planning.

Majekodunmi et al. [17] analysed the impacts of economic growth, energy use, population, urbanization, and tourism on CO_2 emissions in Malaysia using the ARDL approach finds that increases in energy consumption and urbanization significantly raise carbon emissions, while economic growth exhibits a complex relationship often supporting the Environmental Kuznets Curve (EKC) hypothesis. Empirical results indicate that a 1% rise in energy use corresponds to nearly a 0.98% increase in CO_2 emissions, urbanization contributes positively to emissions, and tourism also exacerbates environmental degradation through increased energy demand and infrastructure development. However, the study reveals gaps in capturing heterogeneous regional dynamics within Malaysia, limited examination of the short-run versus long-run effects of tourism on emissions, and insufficient integration of renewable energy penetration and energy mix shifts in the ARDL framework. Further research is needed to incorporate policy variables and sectoral energy consumption data to better understand drivers and mitigation pathways for decarbonization in Malaysia's evolving economic landscape.

With the aid of a panel econometric model and a mediation model, Begum et al. [16] explored the temporal and spatial evolution patterns of urbanization and urban green development, as well as the spatial inequalities and processes that influence urbanization on urban green development. Although there are notable variations within cities in terms of their overall level and growth rate, the data confirm that urbanization and urban green development levels in the YREB have generally improved. In the YREB, urbanization and urban green development exhibit a "U" shaped relationship, in which urbanization initially hinders green development before subsequently facilitating it. Urban agglomerations and middle- and lower-reach cities enjoy organizational and geographic advantages that enhance the impact of urbanization on urban green development. On the other hand, non-urban agglomerations and upper-reaches cities can encourage urban green development at a lower threshold due to their advantages in late development. Furthermore, urbanization has non-linear mediating effects on urban green development.

Lu & Lu [19] investigated the effects of green energy (GE), natural resources (NR), gross savings (GS), financial development (FD), and technological innovation (TI) on Pakistan's economic growth (EG) using symmetric novel ARDL for short- and long-run dynamics, validated by GMM for robustness. Empirical results confirm positive and significant contributions from NR, GS, and FD to EG across both time horizons, underscoring their role as foundational drivers in resource-dependent economies like Pakistan. Conversely, GE utilization and TI show detrimental impacts, attributed to high initial costs, infrastructural gaps, and immature adoption that hinder immediate growth benefits despite long-term sustainability potential.

Using the autoregressive distributed lag model (ARDL) and 30 years of data from 1989 to 2019, [18] in their study investigate the short- and long-term impacts of these variables on Malaysia's environment. The findings provide important new insights, whereas exports and economic growth eventually lead to environmental depletion, population growth, and the development of green technology, which exacerbates environmental degradation. In the medium run, however, the effects of increased exports and population are negligible. The study also accounts for the impact of temporary economic difficulties, such as the COVID-19 pandemic. The report highlights important policy implications for the Malaysian government as a result. First, to mitigate the negative environmental effects of exports, it strongly advises boosting investment in sustainable technology, particularly in the manufacturing sector. Additionally, it recommends raising taxes on non-renewable energy sources and providing subsidies for the purchase of renewable energy to encourage businesses to adopt green technologies.

The effects of different agglomeration activities on urban green development have been the subject of numerous studies. The efficiency of urban green development is greatly enhanced by factors such as population growth. Industrial agglomerations in the manufacturing and finance sectors have also demonstrated signs of spatial convergence with urban green development. A thorough agglomeration systematically encourages the spatial distribution and concentration of elements and industries is a component of the urbanization process. Through the agglomeration effect, this process can have either beneficial or negative effects on the socioeconomic environment and the natural environment [21-24].

While extant literature elucidates the nexus between green technological innovation (GTI), urbanization, and environmental outcomes, such as carbon emission mitigation in Chinese cities [20], U-shaped urbanization-green development dynamics in the Yangtze River Economic Belt [16] and emission drivers in Malaysia via ARDL models [17, 18] it largely neglects their synergistic role as catalysts for economic development, particularly in Malaysia's context. Studies like by Begum et al. [16] highlight GTI's counterintuitive growth deterrence in Pakistan due to infrastructural constraints yet overlook urbanization's moderating influence and spatial heterogeneity within nations, while Malaysian analyses emphasize environmental degradation without integrating GTI-urbanization pathways to GDP enhancement or employment generation. Moreover, methodological gaps persist, including limited mediation analyses of channels like industrial upgrading, foreign direct investment, and renewable energy transitions post-COVID-19, alongside insufficient incorporation of Malaysia's Green Technology Master Plan and regional disparities between Peninsular and East Malaysia. This underscores the imperative for a Malaysia-centric empirical investigation employing spatial econometrics and mediation models to quantify how GTI and urbanization propel sustainable economic growth, addressing the void from macro-environmental diagnostics to growth-oriented policy frameworks.

3. Methodology

This study investigates the impact of capital accumulation, labor force participation, human capital, financial development, urbanization, green technology, information and communication technology (ICT), and foreign direct investment (FDI) on Malaysia's economic growth. Annual time series data covering the period 1991 to 2024 are obtained from the World Development Indicators (WDI) of the World Bank. A summary of the variables is presented in Table 1.

Table 1. Summary of variables

Abbreviation	Variable	Unit
LnGDP	Economic Growth	GDP per capita (constant 2015 US$)
LnCAP	Capital	Gross Fixed Capital Formation (% of GDP)
LnLAB	Total Labor	Labor force, total
LnHC	Human Capital	School enrollment, tertiary (% gross)
LnFD	Financial Development	Broad money (% of GDP)
LnURB	Urbanization	Urban population growth (annual %)
LnTEC	Green Technology	Total Patent applications per capita
LnICT	Information and Communication Technology	Fixed telephone subscriptions
LNFDI	Foreign Direct Investment	Foreign direct investment, net inflows (% of GDP)

Note: WDI stands for World Development Indicator

The origin of the model is based on the endogenous growth model as introduced by Romer (1986), which can be seen as follows:

GDP = f(Capital, Labor, Human Capital)

This paper extends the endogenous model by incorporating all the independent variables as mentioned in Table 1. All variables are transformed into natural logarithms to reduce heteroskedasticity and to allow interpretation of the results in terms of elasticities.:

$$lGDP_{it} = \beta_0 + \beta_1 lCAP_{it} + \beta_2 lLAB_{it} + \beta_3 lHC_{it} + \beta_4 lFD_{it} + \beta_5 lURB_{it} + \beta_6 lTEC_{it} + \beta_7 lICT_{it} + \beta_8 lFDI_{it} + \varepsilon_{it} \quad (1)$$

Let ln represent the logarithm of all variables as mentioned above. The expected coefficients are informed by theory and prior empirical findings. Capital accumulation (β1) is expected to positively drive growth by increasing productive investment. Labor (β2) should support growth through expanded workforce participation, although excess labor without matching demand may yield diminishing effects. Human capital (β3) is expected to influence growth via skill enhancement and productivity improvements positively. Financial development (β4) may enhance growth by expanding credit and liquidity; however, excessive financialization could create vulnerabilities. Urbanization (β5) is hypothesized to contribute positively through agglomeration economies, infrastructure efficiency, and knowledge spillovers, provided urban growth is well managed. Green technology (β6) is expected to promote sustainable long-term growth by enhancing efficiency and reducing environmental costs. ICT development (β7) is expected to support innovation and productivity, while FDI (β8) may promote growth by injecting capital, facilitating technology transfer, and enhancing global market integration.

According to the endogenous growth framework [25], accumulations of capital and labor, the diffusion of knowledge, innovation potential, and the proficiency of institutions together affect long-run economic growth. Also, urbanization positively affects growth due to the agglomeration economies, transaction cost reductions, and knowledge spillover intensifications. Moreover, innovative-driven technologies such as green technologies help to sustain productivity improvements. Also, economic growth stemming from the combined effect of urbanization and green technologies can be explained through various channels such as developed ICT, Foreign Direct Investment (FDI), and Financial Development. ICT can boost urban productivity by creating smoother information exchanges and digital efficiencies as well as using smart city apps. However, the growth of ICT at the urban level is likely to be negative if the digital system is unequally distributed, poorly complemented by adequate skills and industrial advancements, and if digital consumption takes the place of productive use. In theory, FDI encourages endogenous growth in urban areas as it brings new capital, technologies, and promotes learning spillovers, but only if the previous deficiencies in local economies due to lack of low value-added activities and retained profits. Theoretically, finance development encourages growth by directing savings and funding new ideas, however, too rapid or suboptimal financing increases draining of resources, inequality and speculation of the financial system, causing growth to decline in the long term. Therefore, ICT, FDI and finance development are to some extent indicative and that indication reflects the interplay of these elements with urbanization and green technology in economic growth, and the absorption capacity, sectoral distribution and quality of institutions are the strongest elements of the system.

In Malaysia, the measurement of green technology relies on the performance of patenting activities, which resonates with the endogenous growth theory [26]. The logic behind the theory underscores domestic activities related to the absorption of knowledge and innovations in green technologies. The use of this proxy is justified in the context of Malaysia, as the formal system of patenting has been the primary channel of implementation of policies on innovations in green technologies such as the Green Technology Master Plan (2017-2030) and the system of incentives for innovations in vertical policies of the national industrial strategy. The focus on patenting as a variable of interest has been a phenomenon in studies of Malaysia and the ASEAN region largely due to the reliability and availability of data over a long-time frame [11, 13, 18]. Nonetheless, this indicator seems to address/influence the stages of innovations and inventions mainly, lacking in the quality of adoptions and the effectiveness of commercialization, which is especially true for Malaysia as the country relies on the imported green technologies and the policy driven deployment. Hence, it is safe to say, the estimated effects tend to show the increased capacity of the country, especially in innovative activities, to economically grow, and not the overall extent to which green technologies were utilized, hence a gap for future studies.

To examine both the short-run dynamics and long-run relationships among the variables, the Autoregressive Distributed Lag (ARDL) bound testing approach is applied. The ARDL method is particularly suitable because it can handle variables integrated into order I(0), I(1), or a mixture of both, provided none are I(2). It is also efficient for small sample sizes, making it well-suited for annual data spanning 199–2024.

The general ARDL(p,q) specification is:

$$\Delta lGDP_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 lGDP_{t-i} + \sum_{i=0}^{q} \gamma_j \Delta X_{t-j} + \lambda_1 LGDP_{t-1} + \lambda_2 X_{t-1} + \upsilon_t \tag{2}$$

where X denotes the set of independent variables (LCAP, LLAB, LHC, LFD, LURB, LTEC, LICT, LFDI)

The ARDL version of the introduced model is shown in Equation 3 below:

$$\begin{aligned} \Delta lGDP_{it} = {} & \alpha + \sum_{i=1}^{k} \beta_1 lCAP_{j,t-i} + \sum_{i=0}^{l} \beta_2 lLAB_{j,t-i} + \sum_{i=0}^{m} \beta_3 lHC_{j,t-i} + \sum_{i=1}^{n} \beta_4 lFD_{j,t-i} + \sum_{i=0}^{o} \beta_5 lURB_{j,t-i} + \\ & \sum_{i=1}^{p} \beta_6 lTEC_{j,t-i} + \sum_{i=0}^{q} \beta_7 lICT_{j,t-i} + \sum_{i=1}^{r} \beta_8 lFDI_{j,t-i} + \partial_1 lGDP_{j,i-t} + \partial_2 lCAP_{j,i-t} + \partial_3 lLAB_{j,i-t} + \\ & \partial_4 lHC_{j,i-t} + \partial_5 lFD_{j,i-t} + \partial_6 lURB_{j,i-t} + \partial_7 lTEC_{j,i-t} + \partial_8 lICT_{j,i-t} + \partial_9 lFDI_{j,i-t} + \varepsilon_{it} \end{aligned} \tag{3}$$

In Equation 3, εt represents the random error term. The model formulation facilitates the testing of long-run cointegration relationships as well as short-run dynamics through the associated Error Correction Model (ECM). The underlying hypothesis aims to determine whether a stable long-term equilibrium relationship exists between the selected macroeconomic indicators and economic growth in Malaysia.

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8$ (There is no cointegration)

$H_1: \beta_1 \neq \beta_2 \neq \beta_{3_3} \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8$ (There is cointegration)

3.1. Robustness Analysis: FMOLS and CCR

To complement the ARDL results and ensure the robustness of the long-run estimates, this study further employs Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS). Both estimators are widely applied in cointegration analysis as they correct for potential endogeneity and serial correlation problems that may bias conventional OLS estimates in the presence of cointegration.

The FMOLS estimator applies a semi-parametric correction to the OLS framework by adjusting the residuals for both endogeneity and serial correlation. The advantage of FMOLS lies in its ability to generate super-consistent long-run parameter estimates, even in small samples. The FMOLS estimator modifies the above long-run regression to account for serial correlation and endogeneity.

The FMOLS specification is:

$$\beta\text{FMOLS} = \left(\sum_{t-1}^{T}(x_t - \bar{x})\right)^{-1}\left(\sum_{t-1}^{T}(x_t - \bar{x})(LGDP_t - LGDP - T\widehat{\Omega}_{21} + \hat{\Gamma}_{21}\right)^{-1} \tag{4}$$

where:

x_t = (lCAPt, lLABt, LHCt, LFDt, LURBt , LTECt, LICTt, LFDIt)′;

$\widehat{\Omega}_{21}$ = long-run covariance between regressors and error term;

$\hat{\Gamma}_{21}$ = correction term for autocorrelation;

This ensures unbiased and consistent estimates of the long-run coefficients (β_1, …, β_8).

To further validate the robustness of the ARDL estimations, Canonical Cointegrating Regression (CCR) as proposed by Tian et al. [26] is employed. CCR corrects for endogeneity and serial correlation by transforming both the dependent and independent variables using long-run covariance matrices before applying OLS. This transformation ensures asymptotically efficient and unbiased estimates of the cointegrating vectors. The CCR results are compared with those of FMOLS, thereby providing consistency checks on the long-run elasticities of capital, labor, human capital, financial development, urbanization, green technology, ICT, and FDI with respect to Malaysia's economic growth.

$$lGDP^{*}_{t} = \sigma + \beta_1 lCAP^{*}_{t} + \beta_2 lLAB^{*}_{t} + \beta_3 lHC^{*}_{t} + \beta_4 lFD^{*}_{t} + \beta_5 lLURB^{*}_{t} + \beta_6 lTEC^{*}_{t} + \beta_7 lICT^{*}_{t} + \beta_8 lFDI^{*}_{t} + \varepsilon_t \quad (5)$$

Notes: The asterisk indicates that the variables are transformed versions of the original data (yt and xt). These transformations are done to remove endogeneity and serial correlation between regressors and error terms.

By employing both FMOLS and CCR, this study not only addresses econometric concerns but also enhances the robustness of the empirical findings. FMOLS offers non-parametric correction, while DOLS provides parametric adjustment through dynamic modeling. The use of these complementary approaches ensures that the results on the role of capital, labor, human capital, financial development, urbanization, green technology, ICT, and FDI in driving Malaysia's economic growth are both reliable and consistent across alternative estimation methods.

4. Results and Discussion

4.1. ADF Unit Root Assessment

Table 2 presents the results of the ADF unit root tests for the variables LGDP, LCAP, LLAB, LHC, LFD, LURB, LTEC, LICT, and LFDI under the two conditions of intercept and trend. The results provide information regarding the stationary characteristics of the variables.

The variables LGDP, LLAB, LHC, LFD, and LURB are nonstationary at the level under the intercept parameter, indicating the presence of a unit root issue. There is no unit root issue present because other variables have already become stationary at the level. The variables that were not stationary at the level became stationary with a high degree of significance following the first difference.

Except for LLAB and LTEC, most of the variables are stationary at the level of the intercept and trend parameter. Finally, it shows how, after accounting for the initial difference, the unit root problem is eliminated from the nonstationary variables at the level. LLAB and LTEC also become stationary by differencing.

Table 2. ADF Unit Root Assessment

Variables	Intercept		Intercept and trend	
	Level	1st Diff	Level	1st Diff
LGDP	-1.079	-4.895***	-3.624**	-4.875***
LURB	0.846	-3.898***	-3.637**	-3.936**
LTEC	-3.621**	-5.074**	-3.195	-5.075***
LCAP	-3.995***	-7.110***	-3.910**	-7.035***
LLAB	-1.710	-2.111*	-2.438	-2.731
LHC	-1.608	-5.798***	-3.259**	-5.738***
LFD	-1.470	-6.223***	-3.945**	-6.379***
LICT	-4.496***	-2.540	-3.216**	-3.379**
LFDI	-5.402**	-5.411***	-5.573***	-5.417***

Note: ***, **, * represent significant at 1,5 and 10% level, respectively

4.2. Unit Root with a Structural Break Zivot-Andrew's Test

When economic shocks or policy changes may have created structural fractures in the data that standard unit root tests, such as the ADF, can overlook, the ZA test is crucial. During the sample period of this study, Malaysian economy went through some significant structural and policy transition such as, Asian Financial Crisis (1997-1998), industrial revolution during the early 2000s and step forward towards a sustainable green economy after 2010. That's why ZA is employed to identify those structural breaks. Since the ZA test considers these endogenous structural breaks in the data generation process, it also confirms that these breaks would not bias long run estimations and the policy transitions have been considered in the econometric framework. According to the findings in Table 3, at the 1%, 5%, and 10% critical levels, LGDP, LLAB, LFD, LURB, and LTEC do not reject the null hypothesis. Nonetheless, LCAP displays a test statistic of -5.265, demonstrating stationarity with a structural break in 2002, below the 5% essential criterion (-4.80). With a structural break in 1998, the LHC test statistic of -5.155, which is below the 5% threshold value (-4.80), offers compelling proof of stationarity. The ZA statistics for the remaining variables (LICT and LFDI) are likewise below the 1% critical threshold (-5.34), indicating that they become stationary even after considering possible breaks. With structural breaks in 2000 and 2011, their test statistics are 5.579 and -6.494, respectively. It would be incorrect to claim that statistically significant structural fractures exist in every variable. Rather, LGDP, LLAB, LFD, LURB, and LTEC remain non-stationary with possible but statistically unimportant break points, whilst only LCAP, LHC, LICT, and LFDI exhibit definite evidence of break-stationary processes. This indicates that even after taking structural breaks into account, which necessitates an ARDL estimate in the next step, the unit root problem persists for many variables.

Table 3. Unit root with a structural break Zivot-Andrew's test

Variables	ZA statistic	Break	1%	5%	10%	Decision
LGDP	-4.235	2019	-5.34	-4.80	-4.58	No
LURB	-3.458	2008	-5.34	-4.80	-4.58	No
LTEC	-3.666	2006	-5.34	-4.80	-4.58	No
LCAP	-5.265	2002	-5.34	-4.80	-4.58	Yes
LLAB	-1.755	2019	-5.34	-4.80	-4.58	No
LHC	-5.155	1998	-5.34	-4.80	-4.58	Yes
LFD	-3.815	1998	-5.34	-4.80	-4.58	No
LICT	-5.579	2000	-5.34	-4.80	-4.58	Yes
LFDI	-6.494	2011	-5.34	-4.80	-4.58	Yes

4.3. The Bound Assessment

Table 4 compiles the findings of the bound assessment conducted on the variables in the current study. The result shows that the upper limit at the 5% critical value is lower than the bound assessment's F-statistic value of 3.409. The null hypothesis, which posits no cointegration, is rejected at the 5% significance level. The variables in this model, therefore, have cointegrating connections, according to the bound evaluation results. This finding implies that the ARDL technique can be used to estimate the long-term relationship between the variables.

Table 4. The bound assessment

F-statistic		
3.409**		
Critical value		
Significance level	**Lower bound**	**Upper bound**
10 %	1.95	3.06
5 %	2.22	3.39
1 %	2.79	4.1

Note: ** represents significant at 5 % level.

4.4. The ARDL Long-Run Estimations (2, 2, 0, 2, 2, 0, 2, 2, 2)

Table 5 displays the long-term correlations between the independent and dependent variables using the ARDL method. Urbanization is included here as a positive contributing element to the GDP coefficient. Stated differently, URB exacerbates a strong and statistically significant positive impact on income growth suggesting that urbanization enhance infrastructure efficiency, promote knowledge and reduce transaction cost that helps to drive economic growth. The data indicates that a 1% rise in LURB will ultimately lead to a 0.507% increase in economic growth at a 1% relevant level. TEC is another important element that has a meaningful impact on economic development. According to the results, at the 1% significance level, a 1% increase in TEC will eventually result in a 0.099% increase in development that represents increasing innovation capacity, energy efficiency and industrial upgrading. Additionally, LCAP's and LLAB's long-run coefficients are noticeably positive. A 0.019% increase in income growth is positively connected with a 1% increase in CAB. Consequently, LAB contributes to a 1.993% increase in economic development for every unit increase. Another variable, LFDI, also witnessed a positive impact on GDP, but the outcome is not significant.

On the other hand, the HC coefficient is -0.912, which is statistically significant at the 1% level, indicating that a 1% increase in HC will ultimately result in a 0.912% decrease in economic growth indicating the presence of skill mismatch between educated youths and labor demand in the market. Economic development has a significant negative correlation with other factors, such as FD and ICT. At the 1% level, the projected long-run coefficient for FD is -0.078, which is highly significant. According to the findings, a 1% rise in FD will eventually result in a 0.034% decrease in GDP. The outcomes for another variable, ICT, also indicate that a 1% increase in ICT will reduce development by 0.006 % in the long run, but the impact is not significantly notable.

Finally, based on the current study's results, LURB, LTEC, LCAP, and LLAB have a positive influence on the GDP coefficient, which contributes to economic development with a notable significance level. On the other hand, LHC and LFD have a potentially negative impact on GDP, reducing income growth with a notable significance level. LFDI and LICT also have impacts on the economy, but not at a notable or significant level. The projected results provided policymakers with insight into the variables affecting economic development in Malaysia, which could help them make informed decisions for the nation's sustainable development.

Table 5. The ARDL long-run estimations (2, 2, 0, 2, 2, 0, 2, 2, 2)

Variables	Coefficient	t-Statistic	Probability
LURB	0.507***	5.892	0.000
LTEC	0.099**	3.812	0.004
LCAP	0.019***	4.010	0.003
LLAB	1.993***	13.499	0.000
LHC	-0.912***	-10.663	0.000
LFD	-0.078***	-9.753	0.000
LICT	-0.006	-0.698	0.502
LFDI	0.002	0.238	0.817

Note: ***, ** represent significant at 1, and 5% level, respectively.

4.5. The ARDL Short-Run Estimations (2, 2, 0, 2, 2, 0, 2, 2, 2)

Short-run estimations are presented in Table 6, providing important insights into the current study on Malaysia. In this case, the only meaningful finding with a negative coefficient is LHC. Economic development is expected to decrease by 0.359 percent in the short term, with a significant level of 1% for every 1% increase in HC. According to another variable, LFDI, a 1% rise in FDI will, in the short term, lower income growth by 0.001%, albeit this is a negligible effect.

Conversely, LURB, LTEC, LCAP, LLAB, LFD, and LICT all call for an increase in economic development, although the outcomes of LTEC and LFD are not very noteworthy. LURB exhibits a growing effect on economic development, indicating that a 1% increase in URB will, in the short term, increase GDP by 0.528 percent with a high level of significance. Following the same path, LCAP and LLAB show a positive effect on the economic development of 0.013% and 2.076%, respectively, with a per-unit increase in them. Another variable, LICT, also suggests that a 1% increase in ICT leads to a 0.123% increase in economic development in the short run. LTEC and LFD are two variables that positively affect GDP, although the effect is not statistically significant.

Finally, short-run outcomes reveal the remarkably significant impact of urbanization, capital, labor, ICT, and human capital on economic development. At the same time, other variables have no notable effects on GDP in the short-run estimation. The statistical significance at the 1% level, with a t-statistic of -4.751, demonstrates that the error correction mechanism contributed to the correction of departures from the long-term equilibrium, with an adverse coefficient of -1.041.

Table 6. The ARDL short-run estimations (2, 2, 0, 2, 2, 0, 2, 2, 2)

Variables	Coefficient	t-Statistic	Probability
LURB	0.528	6.013	0.000
LTEC	0.013	0.781	0.455
LCAP	0.013	4.954	0.000
LLAB	2.076	5.698	0.000
LHC	-0.359	-3.073	0.013
LFD	0.002	0.159	0.877
LICT	0.123	3.258	0.009
LFDI	-0.001	-0.155	0.879
ECT	-1.041	-4.751	0.001

4.6. Diagnostic Assessments

The goodness of fit of the ARDL model is the last topic covered. For this reason, several diagnostic and stability tests were carried out. The results of the diagnostic tests, which evaluated the model's applicability using Heteroscedasticity, Jarque-Bera, Breusch-Godfrey Serial Correlation, and Ramsey RESET stability assessments, are compiled in Table 7. Because they exceeded the 10% significance level, all the probability values obtained from diagnostic evaluations in this instance were statistically insignificant. It also suggests that the assumptions of heteroscedasticity, serial correlation, model stability, and normality are true and have not been refuted. This suggests that the model has a strong and reliable ability to examine how the factors impact income disparities in Malaysia.

Table 7. The Diagnostic Assessments

Test statistic	F-statistics (Prob.)
Heteroscedasticity test	0.8717(0.6264)
Jarque-Bera	0.5566(0.7571)
Breusch-Godfrey serial correlation	2.4889(0.1575)
Ramsey RESET stability	3.0449 (0.1191)

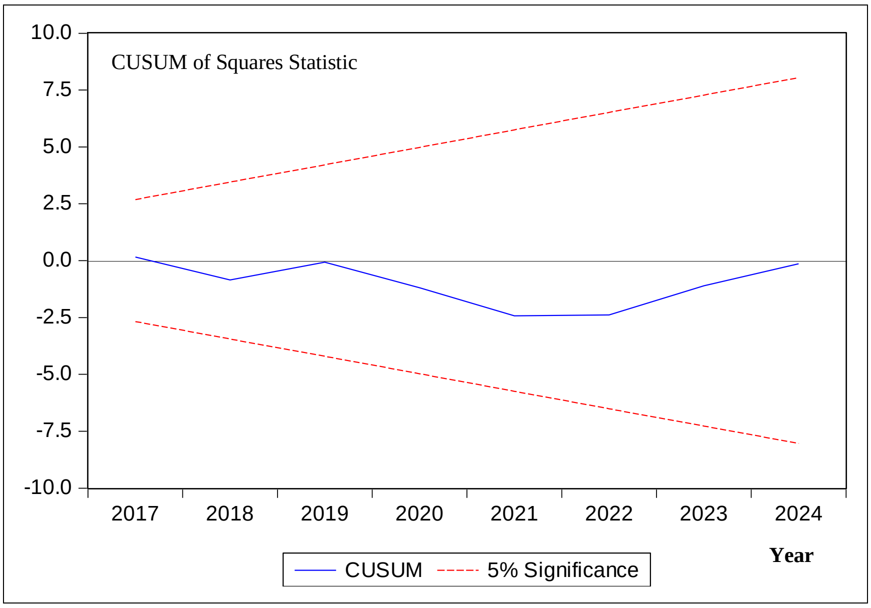
4.7. Robustness Assessment

To monitor reliability and robustness, several robust tests are conducted. To confirm the robustness of the findings, as shown in Table 8, we employed the FMOLS and CCR tests. Like the ARDL estimation, the LHC and LFD estimations supported the FMOLS's significant and negative coefficients. Only LICT yields a different result, although other variables also provide significant coefficients with predicted signs. On the other hand, LCAP and LFD provide positive coefficients in CCR, albeit with negligible likelihood. Other variables with significant coefficients include LLAB, LHC, LURB, LTEC, and LFDI. Lastly, the estimations' values demonstrate how well the model fits the data.

Table 8. Robustness Assessment

Variables	FMOLS		CCR	
	Coefficient	Probability	Coefficient	Probability
LURB	0.798	0.000	1.085	0.011
LTEC	0.062	0.000	0.015	0.774
LCAP	0.005	0.025	-0.003	0.6469
LLAB	3.703	0.000	5.518	0.007
LHC	-0.520	0.000	-0.955	0.013
LFD	-0.074	0.000	0.023	0.349
LICT	0.022	0.000	0.413	0.015
LFDI	0.007	0.047	0.007	0.566

Based on recursive residuals, the CUSUM and CUSUM of squares tests were performed to confirm the structural stability of the ARDL model, assessing the factors that influence income over time. Figure 2 displays the findings of both stability tests. The blue lines for the CUSUM and CUSUM of squares statistics span the entire sample period and fall well under the 5% significance limits. The model's structural stability, dependability, and consistency throughout time are indicated by the presented graphs' (blue dotted lines) continued presence within the bounds.



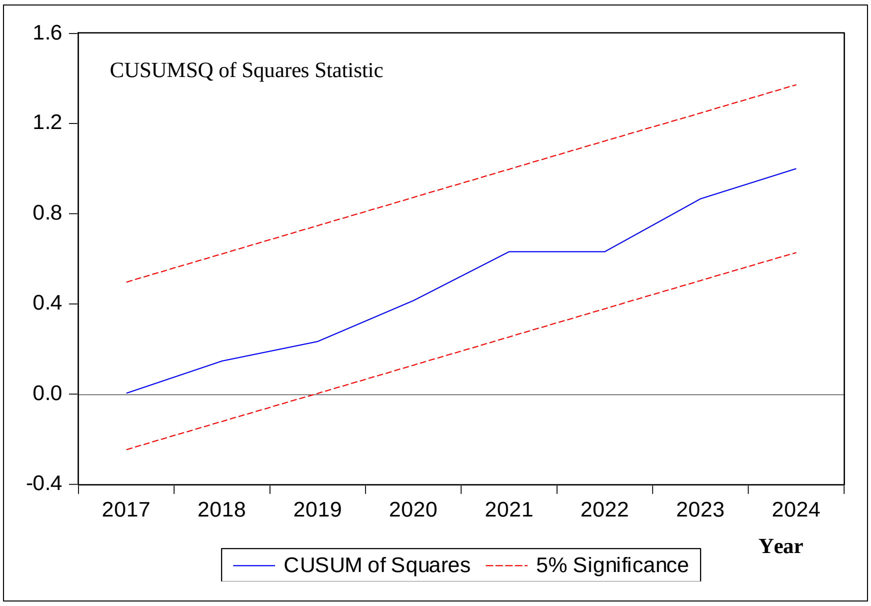


Figure 2. CUSUM and CUSUMSQ

5. Discussion

The study's estimations show how structural, financial, and technical factors interact significantly to shape economic development in Malaysia. Here, urbanization has the most crucial impact on economic development. Urbanization facilitates efficient infrastructure, such as transportation and financial services, resulting in a more robust labor market, lower transaction costs, and increased knowledge spillovers. Both in the short run and long run, urbanization has positive and highly significant coefficients, indicating that it yields both immediate benefits and persistent structural improvements through sustainable investment and infrastructure development. Tian et al. [26], Liu et al. [27], and Haryanto et al. [28] also found similar impacts of urbanization in their studies. They documented that urban capital enhances industrial efficiency and productivity. Strong urban regions, such as Kuala Lumpur, Johor, and Penang, exemplify how urbanization expands markets, enhances labor and capital productivity, and facilitates access to public amenities like healthcare and education, ultimately boosting productivity. While minimizing negative externalities such as pollution, illegal settlements, and traffic, urbanization encourages sectoral shifts from low-productivity agriculture to high-productivity manufacturing and services. Rapid urbanization, however, has the potential to exacerbate environmental degradation and income inequality; therefore, urban policy should strike a balance between sustainable concepts and economic growth.

Another strong contributor to a growing economy is the use of green technology. This study found an insignificant positive effect of technology on economic development, whereas a highly significant impact was observed in the long run. Adoption frictions may be the reason for this. For instance, installing new machinery takes time and comes with expenses that have an impact on GDP. Because research and innovation take time to implement, their effects are not immediately apparent; however, over time, their impact on development becomes evident. Adapting to new technologies and human capital takes time. Therefore, it is impossible to quantify the immediate advantages, but if productivity-boosting technologies spread, the cumulative effects would be significant enough. The national innovation system, which produces new knowledge and production techniques and promotes human development, is strengthened by technological advancement. Guo et al. [20, 29], Xu et al. [30], and Bawono [31] mentioned the similar effects of technology on their studies and suggested that for a long-term sustainable economy implementation of green technology is crucial.

Likewise, labor force participation (LAB) and capital formation (CAP) both support Malaysia's growing economy. Both in the short and long term, CAP produces noteworthy coefficients that demonstrate sustained capital accumulation, improved capital quality, and immediate returns on investment. Higher output can be achieved with capital that has more equipment and better infrastructure. However, this productive capability also increases over time and requires time to transform into large-scale production. The long-term growth of the economy depends on high-quality investment and appropriate returns. Nevertheless, in both situations, it must increase labor productivity since without competent labor, capital cannot be integrated efficiently. Rafindadi et al. [32], Aslan & Altinoz [33], and Yasmeen et al. [34] found similar impacts of capital formation in their studies. Capital and labor forces work compactly for the economic development of a country. Following the same statement, the present study also reveals the positive impact of CAP and LAB on economic development in both the short run and long run. Since Malaysia shifted its production structure to become labor-intensive in key industries, the positive coefficients of LLAB indicate that rising labor participation is closely linked to increasing economic activity. In that instance, migrant labor inflows, female labor participation, and the transition from formal to informal labor all contribute to a higher output, suggesting that labor quantity shocks are swiftly translated into output and that production lasts for a long period. Previous studies also discovered similar results and mentioned that higher labor efficiency with sufficient capitals drives a growing economy [35-37].

However, this study finds that human capital exerts a negative effect on economic progress, a result that is both intriguing and unexpected. While the labor force contributes positively; reflecting Malaysia's expansion driven largely by increases in employment and labor quantity, the negative coefficient on human capital suggests that the quality or relevance of workers' skills may not be fully optimized. One plausible mechanism is skill mismatch, where the education and training received by workers do not align with the competencies demanded by employers. Another related factor is overeducation, in which individuals possess formal qualifications that exceed the skill requirements of their jobs, resulting in underutilization of human capital and lower productivity gains.

These issues point to a systemic misalignment between Malaysia's education system and its evolving production structure, whereby graduates may be well-educated on paper but inadequately prepared for industry-specific skill demands. Such interpretations are consistent with previous studies: Neycheva & Neychev [38] found similar negative effects of human capital on growth, while Maneejuk & Yamaka [39] specifically reported that Malaysia's distinctive education system does not sufficiently match labor market needs, leading to weak alignment between employability and actual skill capability. This combination of mismatch and overeducation provides a credible explanation for the observed negative long-run impact of human capital.

ICT and FD are two other elements that have short-term favourable effects but long-term detrimental effects. By improving market access, digital commerce, and transaction efficiency, the adoption of ICT boosts output immediately. However, for long-term effects, it necessitates skill complements, training investments, reduced costs for digital access, and firm-level restructuring. Like this, FD suggests that the economy may suffer long-term consequences due to instability and inequality, which hinder long-term growth, while the short-term impact is negligible and does not reflect the immediate results of financial expansion. Financial expansion will lead to a plummeting output if it is not accompanied by productive investment, poor productivity signaling misallocation, or structural deficits. Jaapar et al. [40], Ullah et al. [41] and Yousefi [42] described a similar impact in their research papers. Yousefi [42] mentioned that ICT works better in the middle to higher income countries whereas it doesn't have any significance impact on lower income countries. According to this study, FDI is another variable that has insignificant coefficients in the short and long term, suggesting that it is not a significant contributor to economic development. Insignificance could mean that foreign direct investment (FDI) inflows are concentrated in areas with limited absorption capacity for foreign technology, and that profits are repatriated rather than being reinvested. Hussin and Saidin [43] similarly discovered that FDI had a negligible effect on the economic development of the four ASEAN nations.

Lastly, the main drivers of Malaysia's economic development are urbanization, technology, and capital formation with a trained labor force; for better results, human capital and ICT should be leveraged appropriately.

6. Conclusion

This study investigates the impact of capital accumulation, labor force participation, human capital, financial development, urbanization, green technology, ICT, and FDI on Malaysia's economic growth. Annual time series data covering the period 1991 to 2024 are obtained from the World Development Indicators (WDI) of the World Bank. The study utilized the ARDL approach, complemented by robust checks through FMOLS and CCR for the analysis.

The findings highlight that structural and technological drivers have supported Malaysia's economic growth. Urbanization has played a significant role, boosting productivity by enhancing infrastructure, facilitating knowledge spillovers, and promoting labor mobility. Labor force participation and capital accumulation also remain crucial, as they provide the foundation for higher output and industrial development. Green technology contributes positively, showing that innovation and sustainability can reinforce long-term economic progress.

However, the study uncovers weaknesses in human capital and financial development. Despite high levels of educational enrollment, the mismatch between graduates' skills and industry demand has reduced the contribution of human capital. Similarly, financial development has not always translated into productive investments, reflecting issues of inefficiency, inequality, and possible misallocation of resources. ICT shows promising short-term effects but lacks a significant long-term impact without complementary investments in skills and digital infrastructure. FDI, while important in theory, appears to have limited spillover effects due to its concentration in specific sectors and the repatriation of profits.

6.1. Recommendations of the Study

Based on the findings from the analysis, the following recommendations are proposed for the Malaysian Economy:

- Malaysia should strengthen the adoption of green technology to ensure that economic growth is sustainable and environmentally friendly. Incentives should be expanded for industries to adopt renewable energy, energy-efficient production systems, and eco-friendly practices. Existing policies, such as the Green Technology Master Plan (2017–2030) and the National Energy Transition Roadmap*, provide a foundation; however, greater support for the research, development, and commercialization of green innovations is needed.
- To complement green technology, Malaysia should encourage investment in clean infrastructure such as smart grids, public transportation, and low-carbon industrial zones. These efforts align with the Low Carbon Cities Framework (LCCF) and the Smart City Framework†, which promote energy-efficient cities and sustainable living environments. By integrating technology into urban planning, Malaysia can reduce pollution and improve productivity.
- Urbanization policies should focus on balanced and inclusive development, ensuring that rural areas also benefit from infrastructure upgrades and job opportunities. The National Urbanization Policy II (2016–2025) already emphasizes inclusive urban growth. However, more attention should be given to affordable housing, waste management, and access to healthcare and education in rapidly growing cities such as Kuala Lumpur, Johor, and Penang.
- Malaysia should adopt smart city initiatives that integrate digital solutions with sustainable practices to manage congestion, reduce energy consumption, and enhance service delivery. The implementation of the Malaysia Smart City Framework should be expanded to secondary cities to avoid overconcentration of development in major urban centers.
- The government should integrate green urbanization strategies into industrial policies by promoting eco-industrial parks and low-emission transport systems. This will not only support economic development but also reduce the risks of environmental degradation and social inequality. Linking industrial development to sustainable urban mobility plans can make Malaysia's cities more competitive and livable.

6.2. Limitations and Future Studies

This study has some limitations. First, it relies only on annual data, which may not fully capture short-term shocks or seasonal variations in Malaysia's economy. Second, some important variables, such as institutional quality, governance, and environmental regulations, were not included in the analysis, despite playing a critical role in shaping long-term growth. Third, the FDI variable used in this study does not distinguish between different types of investment, such as greenfield investment versus mergers and acquisitions, nor does it identify the specific sectors in which FDI is concentrated. Finally, the measure of ICT is limited to fixed telephone subscriptions, which may not fully represent the impact of modern digital technologies such as mobile broadband, e-commerce, or 5G adoption.

For future studies, researchers should consider including variables such as governance, institutional quality, trade openness, and environmental regulations to provide a more comprehensive understanding of the drivers of economic growth. Future work should also conduct sectoral-level analyses of FDI, such as in manufacturing, services, or technology, to better understand why its overall impact appears weak in Malaysia. Additionally, panel data studies across ASEAN countries would be beneficial in highlighting regional similarities and differences in growth patterns. Future research should also examine the role of digitalization, artificial intelligence, and the adoption of renewable energy, as these factors are becoming increasingly important for sustainable growth.

7. Declarations

7.1. Author Contributions

Conceptualization, A.A.I.I. and S.B.L.; methodology, S.G.; software, S.G.; validation, S.B.L., A.R.R., and B.A.G.; formal analysis, S.G.; investigation, A.R.R.; resources, S.B.L.; data curation, A.A.I.I.; writing—original draft preparation, A.A.L.I.; writing—review and editing, A.R.R. and B.A.G.; visualization, A.R.R. and B.A.G.; supervision, A.R.R. and B.A.G.; project administration, A.R.R. and B.A.G.; funding acquisition, S.B.L. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

* 2023-09_Malaysia's National Energy Transition Roadmap

† LOW CARBON CITIES FRAMEWORK (LCCF) - mylccn.my

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7.4. Institutional Review Board Statement

Not applicable.

7.5. Informed Consent Statement

Not applicable.

7.6. Declaration of Competing Interest

The authors declare that there are no conflicts of interest concerning the publication of this manuscript. Furthermore, all ethical considerations, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

8. References

[1] Kyule, B. M., & Wang, X. (2024). Quantifying the link between industrialization, urbanization, and economic growth over Kenya. Frontiers of Architectural Research, 13(4), 799–808. doi:10.1016/j.foar.2024.03.009.

[2] Li, H., Liu, J., & Wang, H. (2024). Impact of green technology innovation on the quality of regional economic development. International Review of Economics and Finance, 93, 463–476. doi:10.1016/j.iref.2024.05.017.

[3] Chen, S. (2024). Renewable energy technology innovation and urbanization: Insights from China. Sustainable Cities and Society, 102, 105241. doi:10.1016/j.scs.2024.105241.

[4] Sharif, A., Kocak, S., Khan, H. H. A., Uzuner, G., & Tiwari, S. (2023). Demystifying the links between green technology innovation, economic growth, and environmental tax in ASEAN-6 countries: The dynamic role of green energy and green investment. Gondwana Research, 115, 98–106. doi:10.1016/j.gr.2022.11.010.

[5] Shabbir, M. N., & Linh, D. T. (2025). Globalizing green innovation: Impact on green GDP and pathways to sustainability. Research in Economics, 79(1), 101042. doi:10.1016/j.rie.2025.101042.

[6] Gross, J., & Ouyang, Y. (2021). Types of urbanization and economic growth. International Journal of Urban Sciences, 25(1), 71–85. doi:10.1080/12265934.2020.1759447.

[7] Ridwan, M., Urbee, A. J., Voumik, L. C., Das, M. K., Rashid, M., & Esquivias, M. A. (2024). Investigating the environmental Kuznets curve hypothesis with urbanization, industrialization, and service sector for six South Asian Countries: Fresh evidence from Driscoll Kraay standard error. Research in Globalization, 8, 100223. doi:10.1016/j.resglo.2024.100223.

[8] Celik, A., Bajja, S., Radoine, H., Chenal, J., & Bouyghrissi, S. (2024). Effects of urbanization and international trade on economic growth, productivity, and employment: Case of selected countries in Africa. Heliyon, 10(13), 26227. doi:10.1016/j.heliyon.2024.e33539.

[9] Shaban, A., Kourtit, K., & Nijkamp, P. (2024). Reverse causality between urbanization and economic growth: a global test on the validity of urbanization-led economic growth. Annals of Regional Science, 73(4), 1469–1496. doi:10.1007/s00168-024-01315-9.

[10] Wani, M. J. G., Loganathan, N., & Esmail, H. A. H. (2024). Impact of green technology and energy on green economic growth: role of FDI and globalization in G7 economies. Future Business Journal, 10(1), 43. doi:10.1186/s43093-024-00329-1.

[11] Ridzuan, A. R., Kamaludin, M., Ismail, N. A., Razak, M. I. M., & Haron, N. F. (2020). Macroeconomic indicators for electrical consumption demand model in Malaysia. International Journal of Energy Economics and Policy, 10(1), 16–22. doi:10.32479/ijeep.8139.

[12] Si, R., Wang, Y., Cao, M., & Wen, H. (2024). Does green technology innovation promote green economic growth? – Examining regional heterogeneity between resource-based and non-resource-based cities. International Review of Economics and Finance, 94, 103406. doi:10.1016/j.iref.2024.103406.

[13] Xu, Y., Zhang, R., Fan, X., & Wang, Q. (2022). How does green technology innovation affect urbanization? An empirical study from provinces of China. Environmental Science and Pollution Research, 29(24), 36626–36639. doi:10.1007/s11356-021-18117-7.

[14] World Bank. (2025). Urban population (% of total population) – Malaysia: World Development Indicators. World Bank, World Development Indicators. Washington, D.C., United States.

[15] Pan, Y., Teng, T., Wang, S., & Wang, T. (2024). Impact and mechanism of urbanization on urban green development in the Yangtze River Economic Belt. Ecological Indicators, 158, 111612. doi:10.1016/j.ecolind.2024.111612.

[16] Begum, R. A., Raihan, A., Pereira, J. J., Ahmed, F., & Tam, V. W. Y. (2025). Impacts of economic growth, energy use, population, urbanisation, and tourism on CO2 emissions in Malaysia: an empirical analysis of ARDL approach. Environment, Development and Sustainability, 1–29. Development and Sustainability. doi:10.1007/s10668-025-06093-8.

[17] Majekodunmi, T. B., Shaari, M. S., Abidin, N. Z., & Ridzuan, A. R. (2023). Green technology, exports, and CO2 emissions in Malaysia. Heliyon, 9(8), e18625. doi:10.1016/j.heliyon.2023.e18625.

[18] Rehman, A., Ma, H., Liu, R., & Zhang, Y. (2025). Green energy, financial growth, natural resources and technological development: the key driving forces to trigger the economic development. Applied Economics, 1-15. doi:10.1080/00036846.2025.2570947.

[19] Lu, X., & Lu, Z. (2024). How does green technology innovation affect urban carbon emissions? Evidence from Chinese cities. Energy and Buildings, 325, 115025. doi:10.1016/j.enbuild.2024.115025.

[20] Guo, Y., Xie, W., & Yang, Y. (2024). Dual green innovation capability, environmental regulation intensity, and high-quality economic development in China: Can green and growth go together? Finance Research Letters, 63, 105275. doi:10.1016/j.frl.2024.105275.

[21] Yao, J., Xu, P., & Huang, Z. (2021). Impact of urbanization on ecological efficiency in China: An empirical analysis based on provincial panel data. Ecological Indicators, 129, 107827. doi:10.1016/j.ecolind.2021.107827.

[22] Yuan, H., Zhang, T., Feng, Y., Liu, Y., & Ye, X. (2019). Does financial agglomeration promote the green development in China? A spatial spillover perspective. Journal of Cleaner Production, 237, 117808. doi:10.1016/j.jclepro.2019.117808.

[23] Yuan, H., Zou, L., Feng, Y., & Huang, L. (2023). Does manufacturing agglomeration promote or hinder green development efficiency? Evidence from Yangtze River Economic Belt, China. Environmental Science and Pollution Research, 30(34), 81801–81822. doi:10.1007/s11356-022-20537-y.

[24] Romer, P. M. (1986). Increasing Returns and Long-Run Growth. Journal of Political Economy, 94(5), 1002–1037. doi:10.1086/261420.

[25] Park, J. Y. (1992). Canonical Cointegrating Regressions. Econometrica, 60(1), 119. doi:10.2307/2951679.

[26] Tian, J., Abbasi, K. R., Radulescu, M., Jaradat, M., & Barbulescu, M. (2024). Reevaluating energy progress: An in-depth policy framework of energy, urbanization, and economic development. Energy Policy, 191, 114196. doi:10.1016/j.enpol.2024.114196.

[27] Liu, Y., Yang, M., & Cui, J. (2024). Urbanization, economic agglomeration and economic growth. Heliyon, 10(1), e23772. doi:10.1016/j.heliyon.2023.e23772.

[28] Haryanto, T., Erlando, A., & Utomo, Y. (2021). The relationship between urbanization, education, and GDP per capita in Indonesia. The Journal of Asian Finance, Economics and Business, 8(5), 561-572. doi:10.13106/jafeb.2021.vol8.no5.0561.

[29] Guo, X., Deng, M., Wang, X., & Yang, X. (2024). Population agglomeration in Chinese cities: is it benefit or damage for the quality of economic development? Environmental Science and Pollution Research, 31(7), 10106–10118. doi:10.1007/s11356-023-25220-4.

[30] Xu, A., Song, M., Xu, S., & Wang, W. (2024). Accelerated green patent examination and innovation benefits: An analysis of private economic value and public environmental benefits. Technological Forecasting and Social Change, 200, 123105. doi:10.1016/j.techfore.2023.123105.

[31] Bawono, S. (2021). Human capital, technology, and economic growth: A case study of Indonesia. Journal of Asian Finance, Economics and Business, 8(5), 29-35. doi:10.13106/jafeb.2021.vol8.no5.0029.

[32] Rafindadi, A. A., Isah, A. B., & Usman, O. (2024). Economic development and energy consumption in Saudi Arabian economy: do globalization, financial development and capital accumulation matter? International Journal of Energy Sector Management, 18(6), 1423–1443. doi:10.1108/IJESM-07-2023-0026.

[33] Aslan, A., & Altinoz, B. (2021). The impact of natural resources and gross capital formation on economic growth in the context of globalization: evidence from developing countries on the continent of Europe, Asia, Africa, and America. Environmental Science and Pollution Research, 28(26), 33794–33805. doi:10.1007/s11356-021-12979-7.

[34] Yasmeen, H., Tan, Q., Zameer, H., Vo, X. V., & Shahbaz, M. (2021). Discovering the relationship between natural resources, energy consumption, gross capital formation with economic growth: Can lower financial openness change the curse into blessing. Resources Policy, 71, 102013. doi:10.1016/j.resourpol.2021.102013.

[35] Zhang, C., Waris, U., Qian, L., Irfan, M., & Rehman, M. A. (2024). Unleashing the dynamic linkages among natural resources, economic complexity, and sustainable economic growth: Evidence from G-20 countries. Sustainable Development, 32(4), 3736–3752. doi:10.1002/sd.2845.

[36] Islam, M. S., & Alhamad, I. A. (2023). Do personal remittance outflows impede economic growth in Saudi Arabia? The role of trade, labor force, human, and physical capital. Humanities and Social Sciences Communications, 10(1), 1–9. doi:10.1057/s41599-023-01607-z.

[37] Imsar, I., Tambunan, K., Silviani, R., & Harahap, M. I. (2022). The Effect of Export, Islamic Mutual Fund, and Labor Force on Economic Growth in Indonesia. At-Tijaroh: Jurnal Ilmu Manajemen Dan Bisnis Islam, 8(1), 104–114. doi:10.24952/tijaroh.v8i1.4580.

[38] Neycheva, M., & Neychev, I. (2020). Overeducation and Economic Growth: Theoretical Background and Empirical Findings for the Region of Central and Eastern Europe. Ikonomicheski Izsledvania, 29(5), 124–142.

[39] Maneejuk, P., & Yamaka, W. (2021). The impact of higher education on economic growth in asean-5 countries. Sustainability (Switzerland), 13(2), 1–28. doi:10.3390/su13020520.

[40] Mohd. Jaapar, A., Aziz, A. B., & Ahmad Chukari, N. (2025). Financial Development Impact towards Economic Growth and Income Inequality in 5-Asean Countries. Semarak International Journal in Modern Accounting and Finance, 1(1), 29–47. doi:10.37934/sijmaf.1.1.2947a.

[41] Ullah, W., Zubir, A. S. M., & Ariff, A. M. (2024). Non-linearities Caused by “Too Much Finance Effect”: Exploring the Myth and Reality for Developed and Developing Countries. SAGE Open, 14(3), 1-21. doi:10.1177/21582440241267142.

[42] Yousefi, A. (2011). The impact of information and communication technology on economic growth: Evidence from developed and developing countries. Economics of Innovation and New Technology, 20(6), 581–596. doi:10.1080/10438599.2010.544470.

[43] Hussin, F., & Saidin, N. (2012). Economic Growth in ASEAN-4 Countries: A Panel Data Analysis. International Journal of Economics and Finance, 4(9), 119–129. doi:10.5539/ijef.v4n9p119.